

**NATIONAL TRANSPORTATION SAFETY BOARD**

Office of Research and Engineering

Washington, D.C.

June 21, 1999

**Sound Spectrum Study Cockpit Voice Recorder**

**A. ACCIDENT**

DCA98RA013

Location : Palembang, Indonesia  
Date : December 19, 1997  
Time : About 1614 Local Time  
Aircraft : Silk Air Flight MI-185, a Boeing B-737-36N,  
9V-TRF

**B. GROUP IDENTIFICATION**

Chairman : James Cash  
NTSB

Members: : Professor O. Diran,  
IIC, Air Accident Investigation Commission, Indonesia

Captain Santoso Sayogo,  
Deputy IIC, Air Accident Investigation Commission, Indonesia

Don Boston  
Boeing Commercial Airplane Group

Kenneth Kell  
Air Accident Investigation Commission

**C. SUMMARY**

The aircraft was equipped with an Allied Signal solid state 2Hr cockpit voice recorder (CVR) part number 980-6022-001 S/N unk.

The crash memory module was recovered from the Musi River and transported to the NTSB laboratory immersed in water. The memory was removed from the crash case and an excellent quality 2 hour and 1 minute and 11 second recording was obtained. The CVR contained about 29 minutes of the inbound flight and landing at Jakarta. The recording contained the ground operations and take off from Jakarta and about 30 minutes 25.4 seconds of the accident flight. The recording stopped approximately 7 minutes and 48 seconds prior to the aircraft

impacting the ground.<sup>1</sup>

## **D: DETAILS OF INVESTIGATION**

### **Flight – Ground Test Documentation**

To further document why the CVR stopped prior to the final impact, an additional flight test was conducted on October 16, 1998. This test was flown and supervised by the Indonesian investigation authority. The aircraft that was used in the test was an identical SilkAir Boeing 737 aircraft 9V-TRA.

During the test an identical Allied Signal SSCVR 2-hr recorder was installed on the test aircraft to record all of the various test conditions. Several tests were conducted where a person manually pulled the CVR's circuit breaker in the cockpit both. The manual pulls were characterized as a "hard" pull and a "soft" pull condition. In addition to the manual circuit breaker pulls, several seatbelt unbuckle operations and seatbelt banging on the floor were performed.

All 4 channels of the accident recording were digitized for analysis by the Safety Board's signal processing software. The accident recording is documented in Chart 1,2 and 3 of the original report. The traces are CVR channel 1, 2, 3, 4 top to bottom. The x-axis is elapse time in seconds and the y-axis is amplitude of the corresponding signals. The most active channel is CVR channel 4 or the area microphone channel.

10/16/98 1999 Airborne tests:

Chart A	Test condition 001 airborne test CVR C/B Pull waveform
Chart A1	Test condition 001 airborne test CVR C/B Pull spectrogram
Chart B	Test condition 001a airborne test CVR C/B Pull waveform
Chart B1	Test condition 001a airborne test CVR C/B Pull spectrogram
Chart C	Test condition 002 airborne test CVR C/B Hard Pull waveform
Chart C1	Test condition 002 airborne test CVR C/B Hard Pull spectrogram
Chart D	Test condition 003 airborne test CVR String Pull waveform
Chart D1	Test condition 003 airborne test CVR String Pull spectrogram

### **Manual Circuit Breaker Pulls**

The last set of tests was to examine the sound signatures that were generated when the CVR cockpit circuit breaker was pulled. To validate whether the circuit breaker manual pull sounds could be heard above the normal in-flight

---

<sup>1</sup> Aircraft impact time was established by correlating recorder ground radar data with the CVR/DFDR data.

cockpit sounds, the circuit breaker tests were conducted during the in-flight test. Test conditions 1, 1a, 2, and 3 were accomplished to document the sounds that were recorded on the CVR during a "soft" "hard" and string pull of the CVR circuit breaker. Charts A1, B1, C1 are spectrographs of the area microphone channel of the CVR several seconds prior to the CVR stopping. It can be seen from the charts that no identifiable sound signatures were recorded on the CVR. The addition of the background cockpit noise that is present during normal cruise totally obscured any sounds associated with the manual pulling of the cockpit circuit breaker.

### **Captain Seat Belt Noise**

To further understand several seatbelt "clunk" sounds heard during the last few seconds of the accident recording several test seatbelt clunks were compared to the test recording. (Conditions 7, 8).

The accident aircraft was equipped and the flight crew was wearing headsets with "hot" boom microphones in addition to the normal cockpit area microphone. It is believed that the Captain on the accident flight had removed his headset sometime prior to the end of the recording. While no positive determination could be made as to where he placed the headset, it can be expected that the headset was placed or hung somewhere to the left of the Captain's seat. It also appeared that the co-pilot had continued to wear his headset during the entire flight.

In the accident recording the sounds of the seatbelt clunk were picked up on the area mike (channel 4) of the CVR. This is shown in Charts G, G1 and H, H1. The sounds were also picked up by the captain's (channel-2) channel and the co-pilot's (channel-3) of the CVR recording. CVR channel-1 contained no cockpit audio information. This channel contained only air traffic control radio information.

#### **10/16/98 1999 Airborne tests:**

Chart E	Test condition 007 airborne test Captains right seatbelt waveform
Chart E1	Test condition 007 airborne test Captains right seatbelt spectrogram
Chart F	Test condition 008 airborne test Captains left seatbelt waveform
Chart F1	Test condition 008 airborne test Captains left seatbelt spectrogram

#### **Accident CVR recording:**

Chart G	Accident recording 4-channel waveform
Chart G1	Accident recording 4-channel spectrogram
Chart H	Accident recording 4-channel waveform cont.
Chart H1	Accident recording 4-channel spectrogram cont.

It can be seen from the test flight charts (Charts E, E1) that the clunk sound associated with the right Captain's seatbelt was of sufficient intensity to be observed in all 3 of the CVR channels. The sounds associated with left hand portion of the Captain's seatbelt was only loud enough to be picked up on the area microphone and the 1<sup>st</sup> Officer's hot mike. (Chart F, F1) In this test there were no sound signatures observed on the Captain's hot microphone channel of the CVR.

### **Air Traffic Control Voice Comparison.**

When the accident aircraft's CVR recording was compared to the air traffic control's recording of Jakarta Center it was observed that there was one routine radio transmission from the accident aircraft that wasn't found on the accident CVR recording. The accident aircraft flew almost 8 minutes after the CVR unexpectedly stopped recording. During this 8 minutes one radio transmission, a normal aircraft position report, was recorded on the ground air traffic control. A comparison was made between several words found in the air traffic control transmission and with the same words found on the CVR recording.

#### **Accident CVR recording:**

Chart I	1st Officers radio transmission spectrogram with formants
Chart J	Expanded scale 1st Officers radio transmission spectrogram

#### **Jakarta Air Traffic Control Recording:**

Chart K	Suspected 1st Officers radio transmission spectrogram with formants
Chart L	Expanded scale suspected 1st Officers radio transmission spectrogram

During the accident flight, the 1<sup>st</sup> officer was making all of the air to ground radio transmissions. During most of these transmissions he would say the flight's call sign of "SilkAir one eight five". This portion of the radio transmission was used to compare the last air traffic control radio transmission with previous transmissions from the flight. Charts J and I document what the "voice print" characteristics of the CVR radio transmission look like. These plots depict the various frequency patterns of the 1<sup>st</sup> officer's voice. To further define the voice characteristics of the 1<sup>st</sup> officer, computer generated vocal formant information is overlaid on top of the voiceprint (Chart I). The vocal formant information is a computer generated vocal cavity modeling software that models the human mouth, tongue, lips and voice box. This formant representation is unique to an individual and represents how they position their mouth, tongue and lips when they speak.

Charts K and L represent the voice information from the last radio transmission recorded from the accident aircraft. Again Chart K is the voice print information with the computer overlay formants on it. The same aircraft call sign "SilkAir one eight five" was spoken in the beginning of this transmission. It can be seen from the comparison of the

two charts that the formant information is almost identical between these two segments. The most notable comparison is when the 1<sup>st</sup> officer says the call sign "SilkAir"

### Summary

1. Normal in-flight background noise completely obscures any noise that a manual circuit breaker pull makes.
2. The SilkAir in-flight circuit breaker test of 10/16/98 closely matches the data obtained from the Boeing in-flight test.
3. If the circuit breaker can be pulled without making any noise, there are no other unique electronic sound signatures recorded on the CVR.
4. On the accident recording the sounds originating from the seat belt buckle hitting the floor is picked up by the 3 cockpit microphones (cockpit area mike, Captain's hot mike, 1<sup>st</sup> Officer's hot mike)
5. During test flight, all 3-cockpit (cockpit area mike, Captain's hot mike, 1<sup>st</sup> Officer's hot mike) microphones picked up the sounds made by the right side of Captain's seat belt buckle hitting the floor.
6. During test flight, the sounds made by the left side of Captain's seat belt buckle hitting the floor was picked up by cockpit area mike and by 1<sup>st</sup> officer's hot microphone.
7. The final radio transmission recorded on the air traffic control tape from the accident aircraft was made after the CVR has stopped recording.
8. The 1<sup>st</sup> officer was making all of the radio calls on the accident CVR recording.
9. The speech characteristics of the 1<sup>st</sup> officer's radio calls were compared to the last radio transmission.
10. The call sign portion of the 1<sup>st</sup> officer's CVR transmissions matched the same call sign portion as recorded on the last ATC radio transmission

James R. Cash  
Electronics Engineer

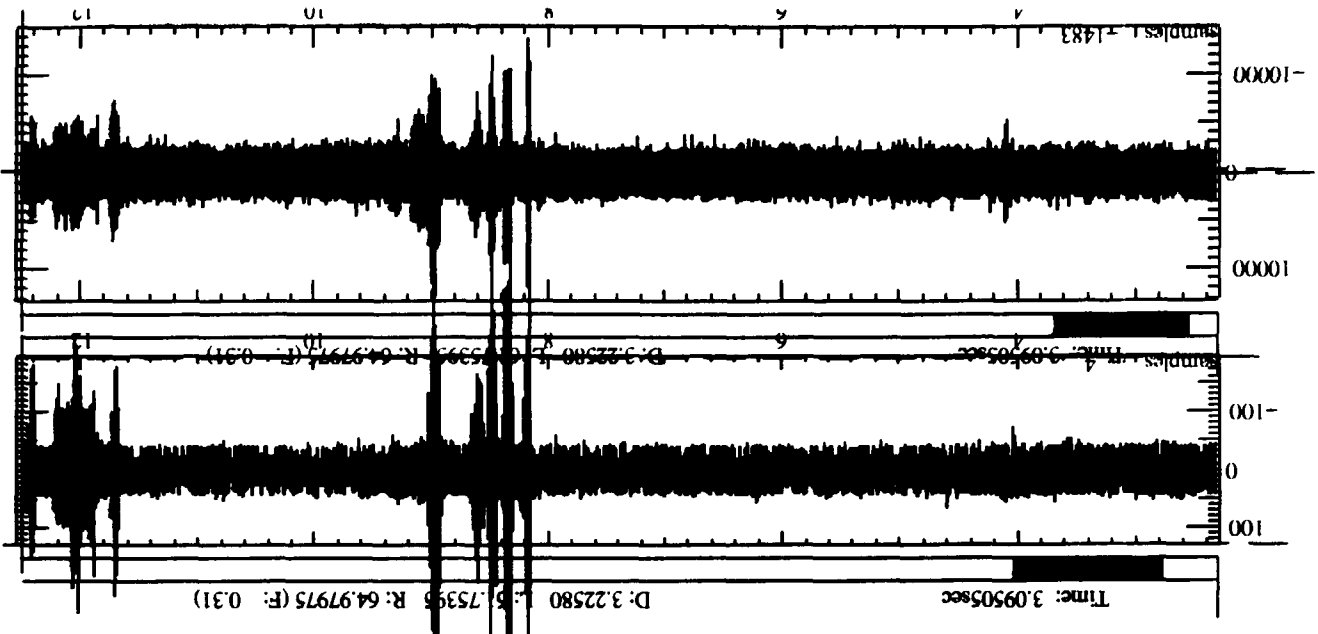
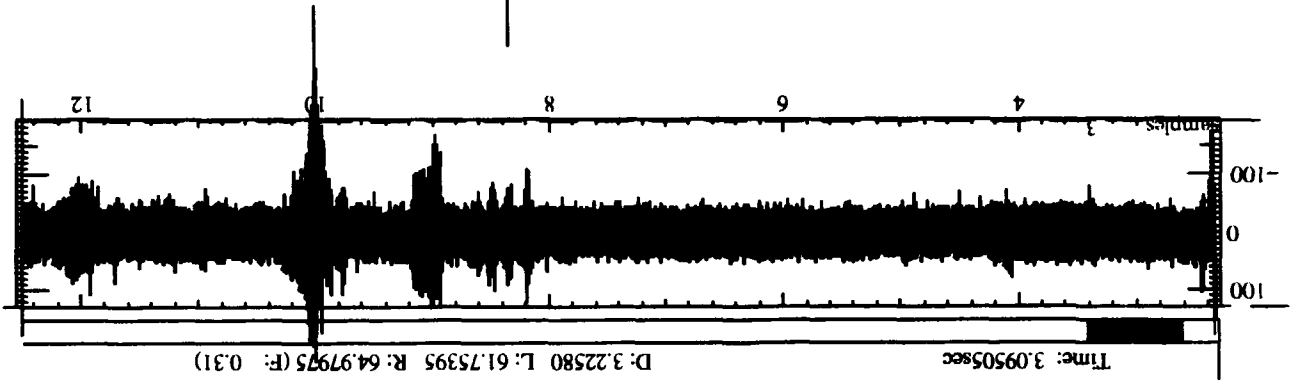
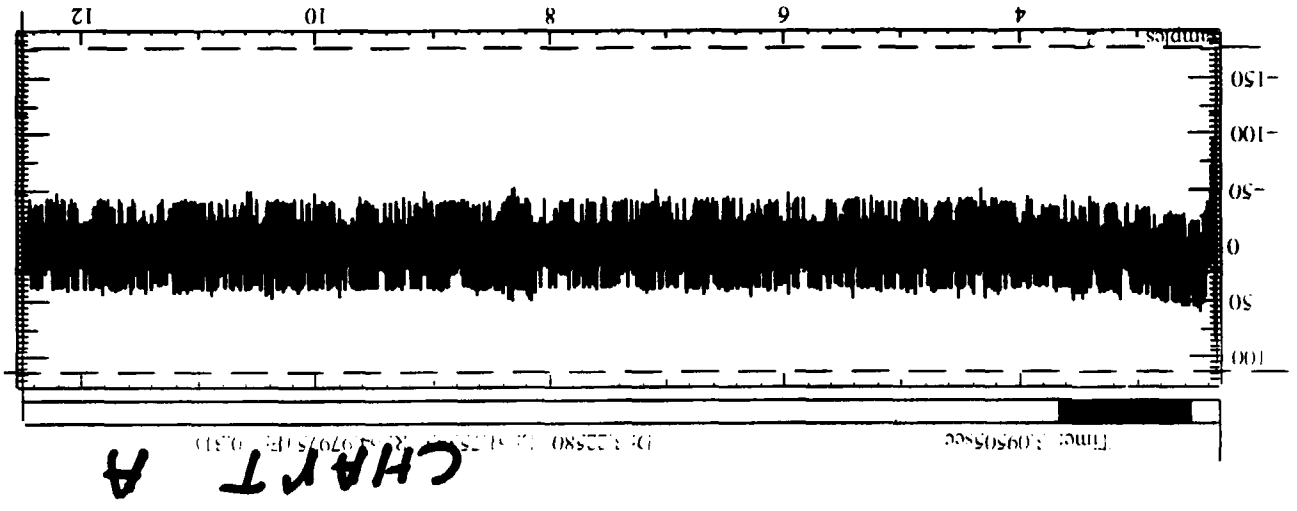


CHART A



3.6780 Freq: 7265.62 Value: 61 D: 9.26070 L: 2.99445 R: 12.25515 (F: 0.11)



3.6780 Freq: 7265.62 Value: 160.5 D: 9.26070 L: 2.99445 R: 12.25515 (F: 0.11)



3.6780 Freq: 7265.62 Value: 10 D: 9.26070 L: 2.99445 R: 12.25515 (F: 0.11)



3.6780 Freq: 7265.62 Value: 10 D: 9.26070 L: 2.99445 R: 12.25515 (F: 0.11)

CH-1 #1

CH-4

CH-3

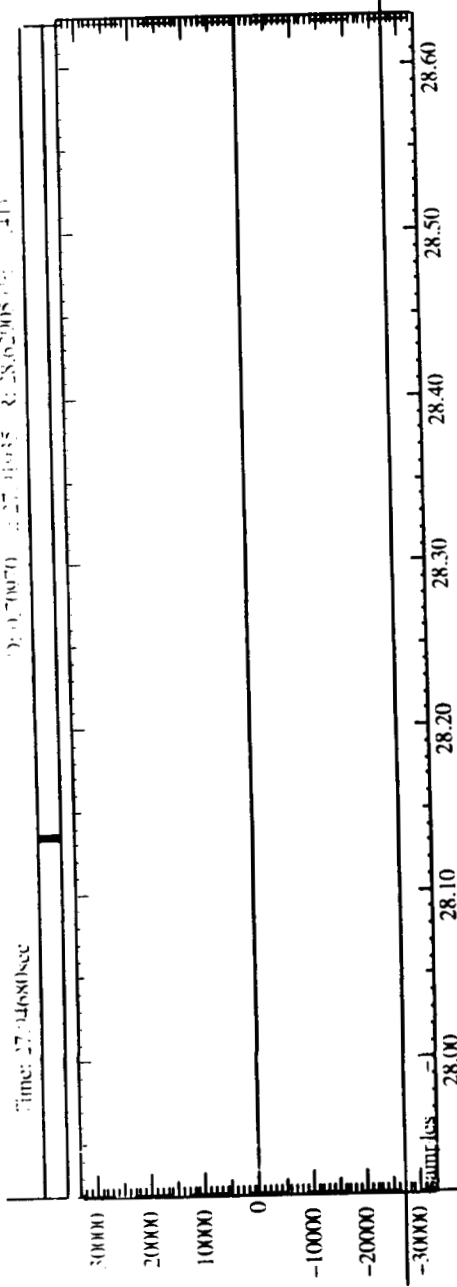
CH-2

CH-1

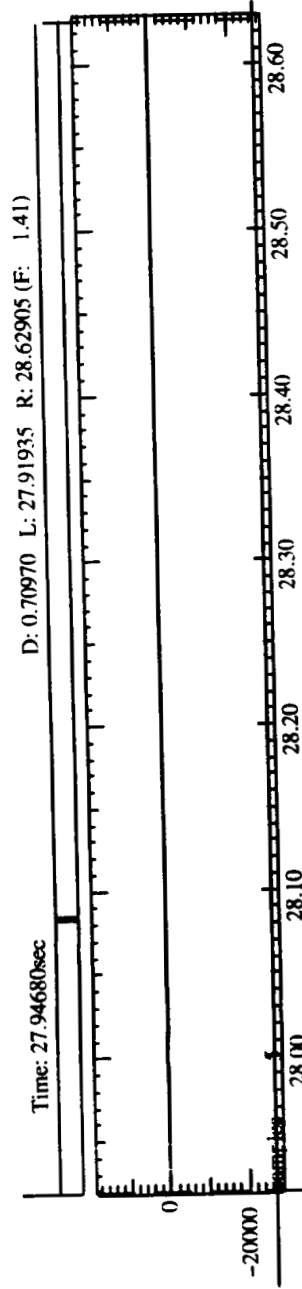
7

# CHART B

Time: 27.94680sec

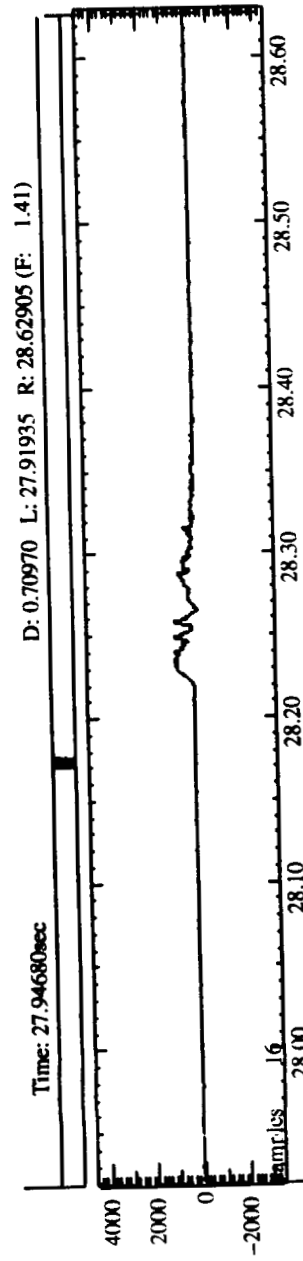


CH-1

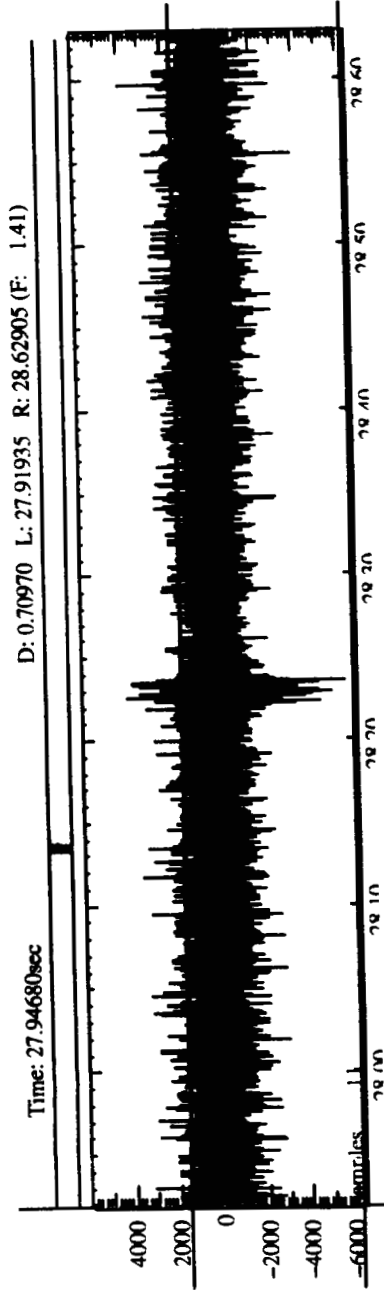


CH-2

1a



CH-3



CH-4

2

9

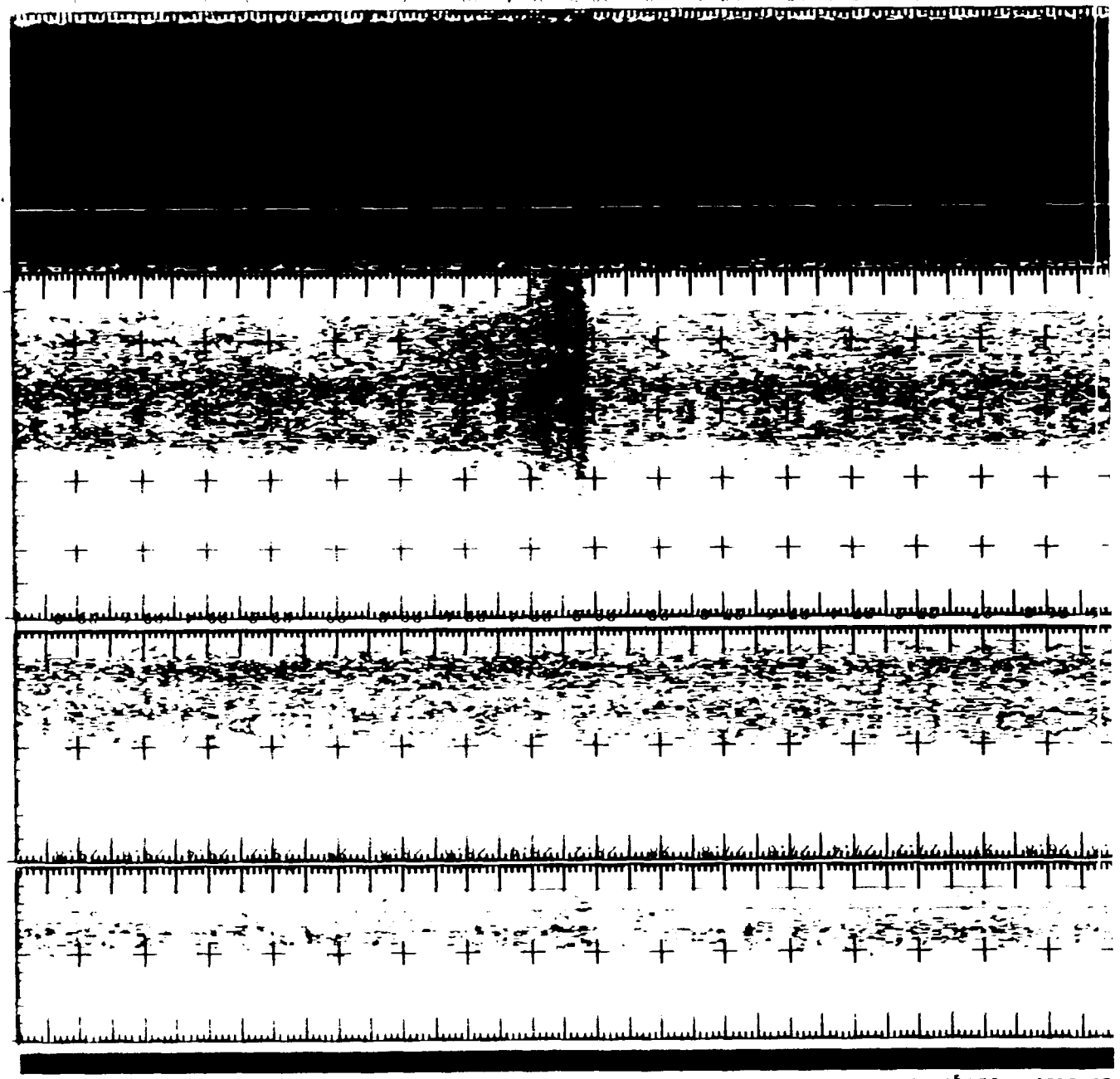


CH-4

CH-3

CH-2

CH-1



26.6459 Freq: 7037.04 Value: 30 D: 3.68030 L: 26.33430 R: 30.01460 (F: 0.27)

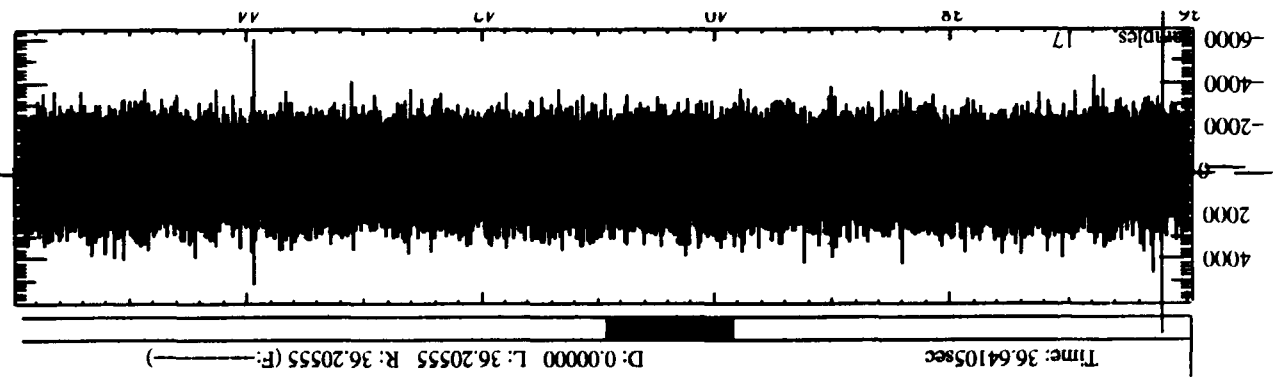
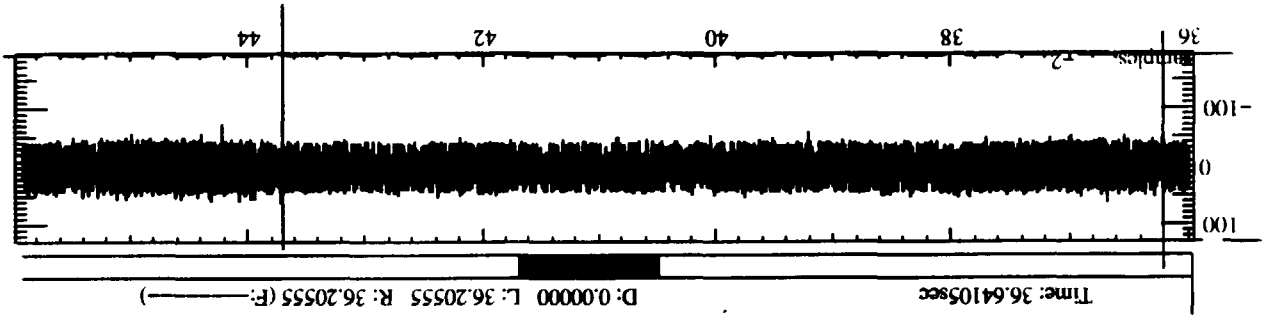
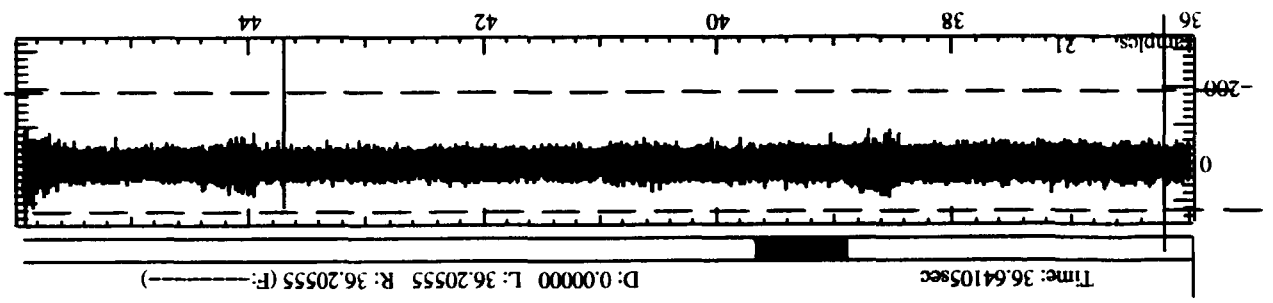
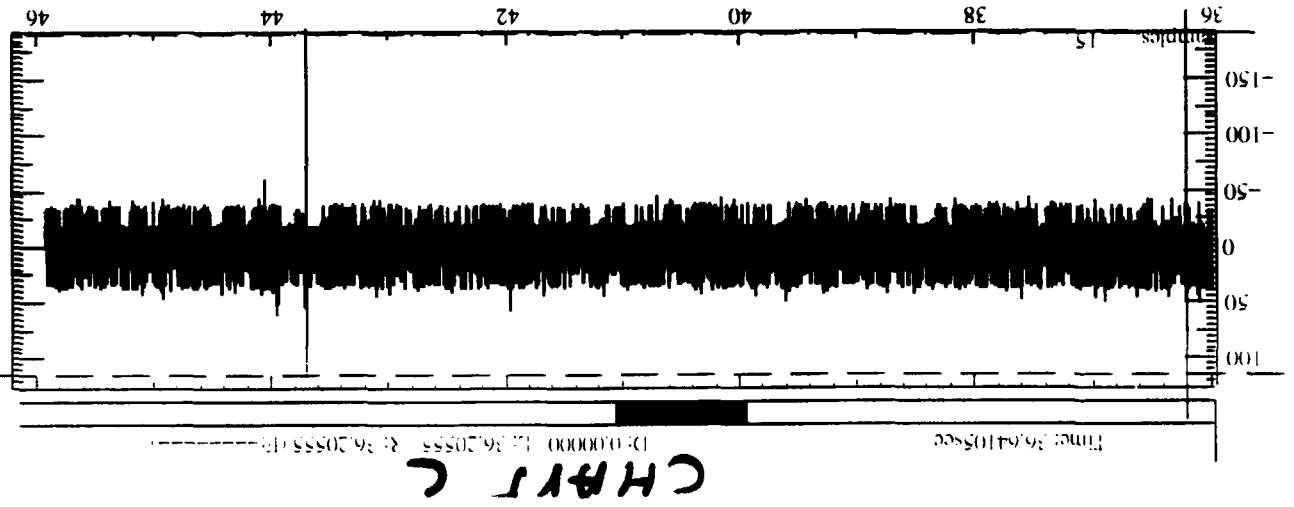


CHART C

2  
cond

37.1361 Freq: 5695.36 Value: 25 D: 9.81840 L: 36.20250 R: 46.02090 (F: 0.10)

CH-1

CH-1

CH-2

CH-3

CH-4

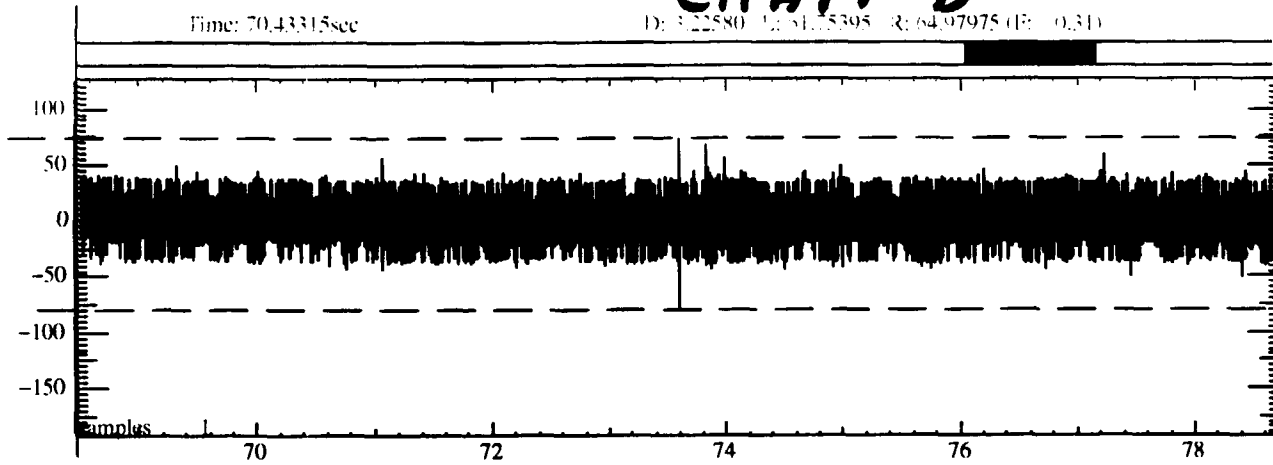
11

1  
43  
44  
45  
46  
47  
48  
49  
50

# CHART D

Time: 70.43315sec

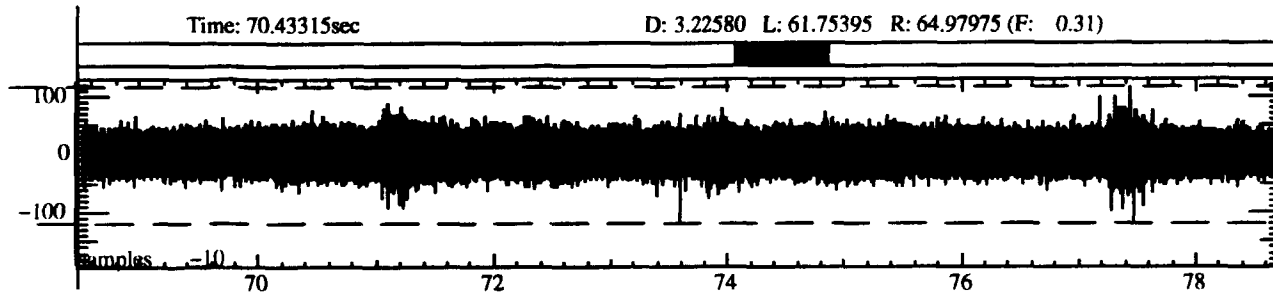
D: 3.22580 L: 61.75395 R: 64.97975 (F: 0.31)



CH-1

Time: 70.43315sec

D: 3.22580 L: 61.75395 R: 64.97975 (F: 0.31)

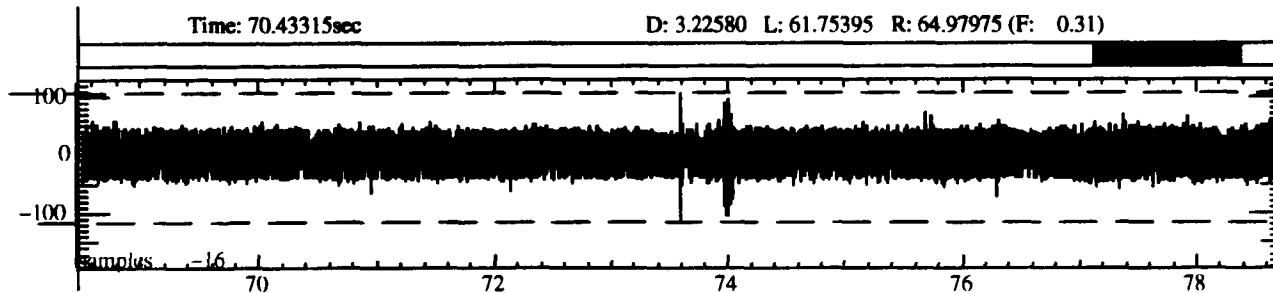


CH-2

CONF 3

Time: 70.43315sec

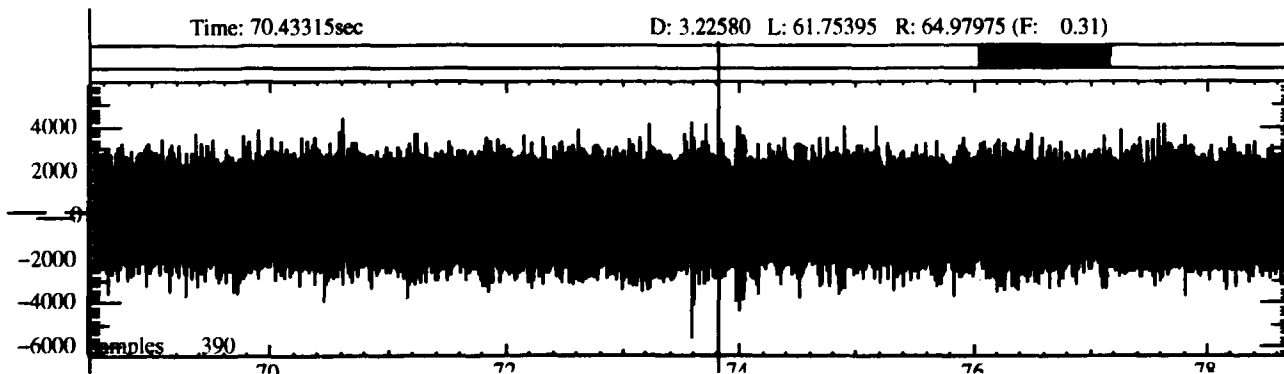
D: 3.22580 L: 61.75395 R: 64.97975 (F: 0.31)



CH-3

Time: 70.43315sec

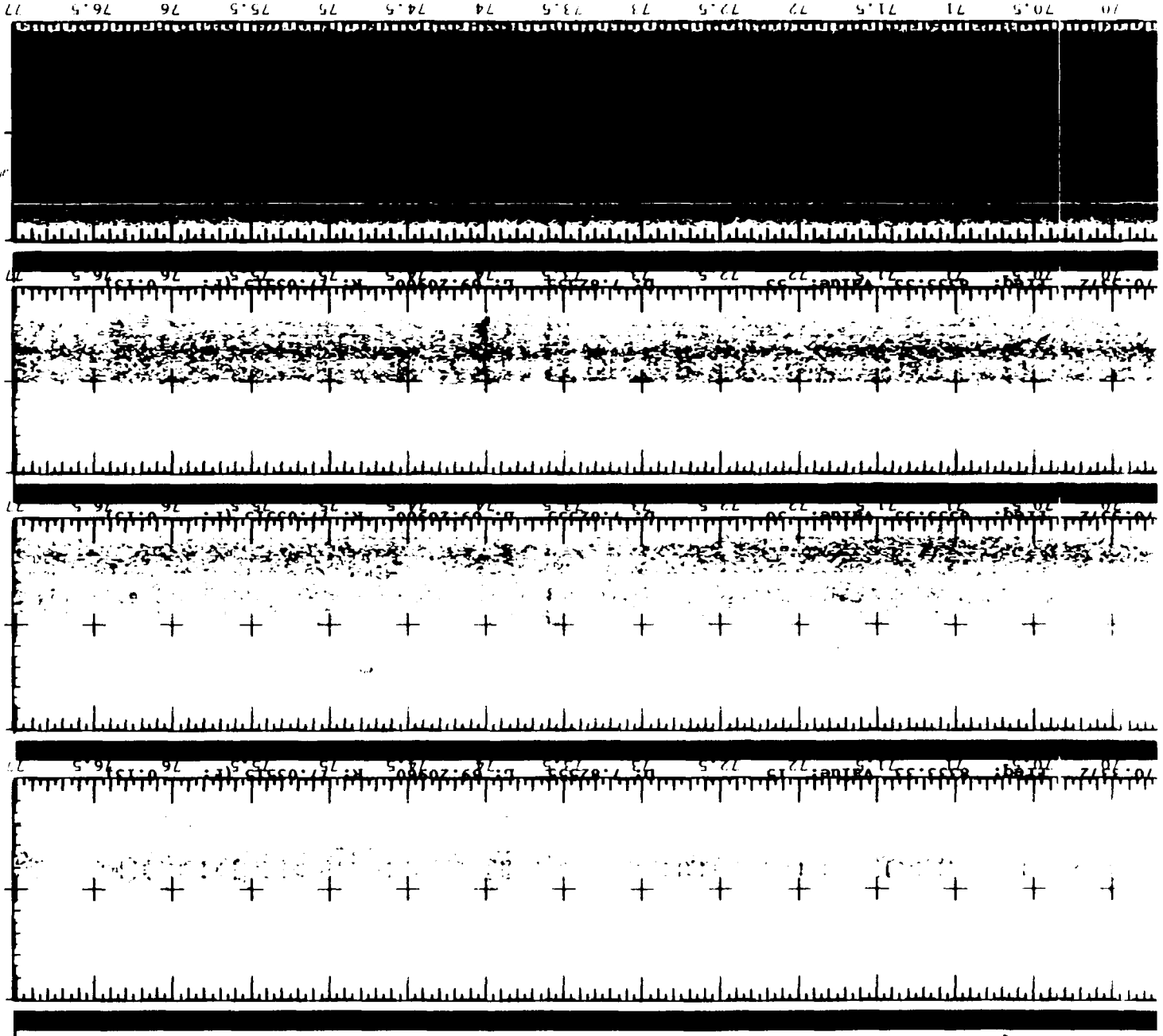
D: 3.22580 L: 61.75395 R: 64.97975 (F: 0.31)



CH-4

13

Loss  
Power



CH-4

CH-3

CH-2

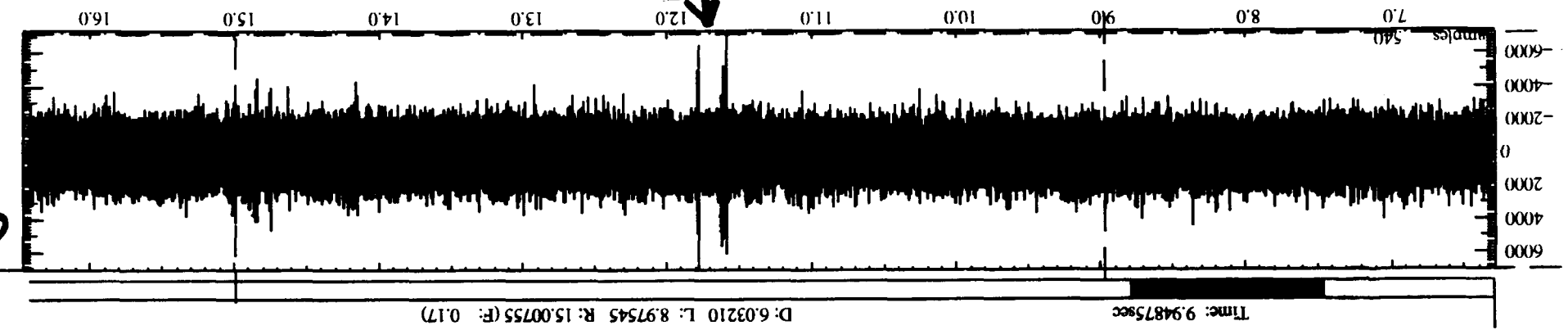
CH-1

70.3372 Freq: 8333.33 Value: 29 D: 7.82555 L: 69.20960 R: 77.03515 (F: 0.13)

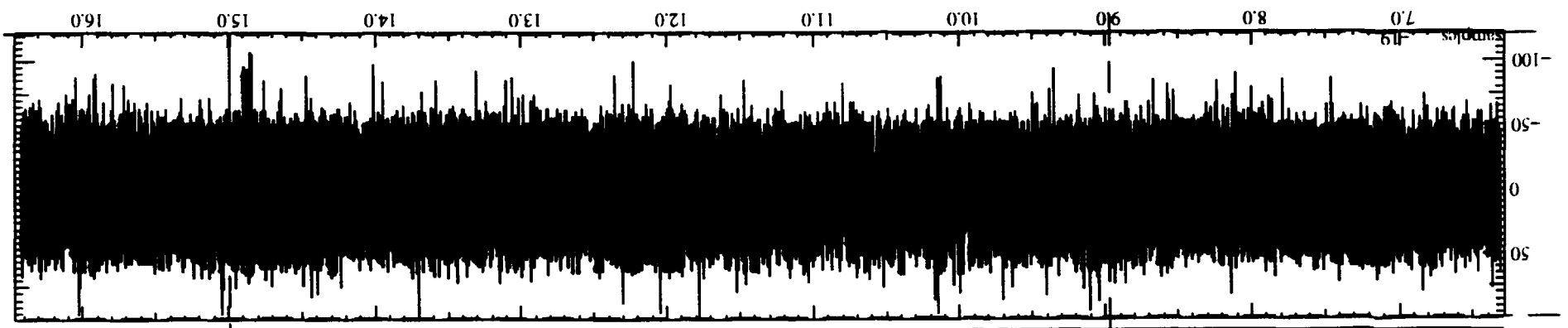
sear Bolt  
CUMH  
7

14

CH4



CH3



CH2

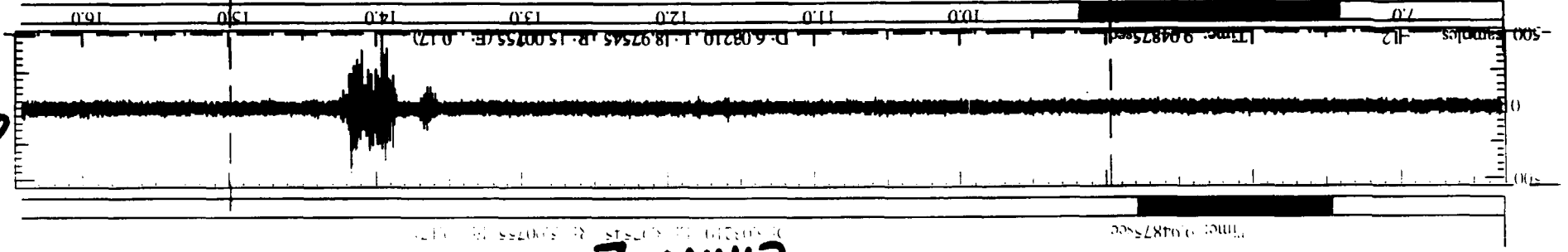


CHART E

9.5810 Freq: 6750.00 Value: 23 D: 6.03210 L: 8.97545 R: 15.00755 (F: 0.17)

CH2

10.5 11 11.5 12 12.5 13 13.5 14 14.5



9.5810 Freq: 6750.00 Value: 36 D: 6.03210 L: 8.97545 R: 15.00755 (F: 0.17)

CH-3

CH-4

10 10.5 11 11.5 12 12.5 13 13.5 14 14.5



EAR  
L  
4

15

SEAT BELT  
CIRCUIT

CH-8

CH-4

CH-1

CH-2

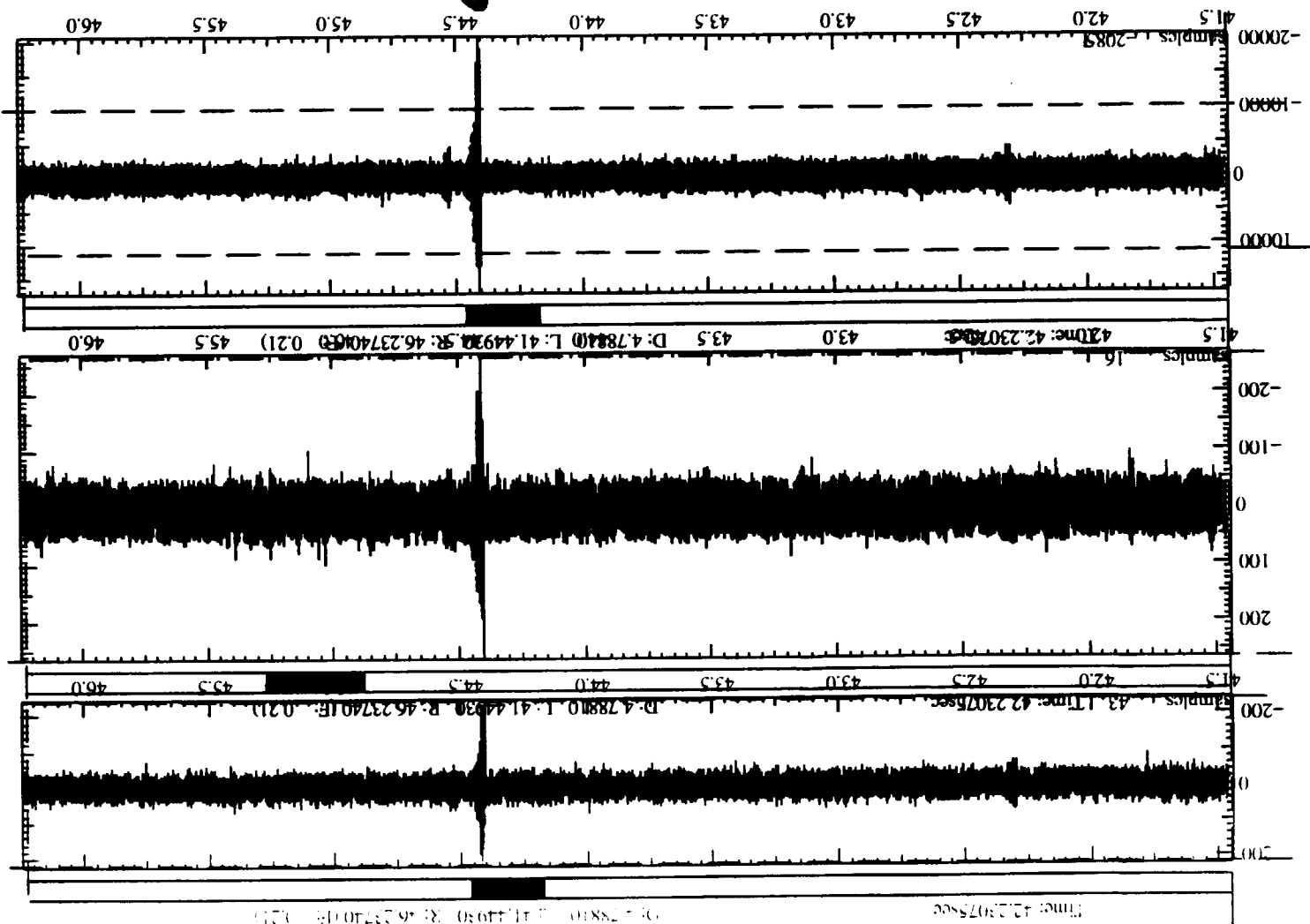
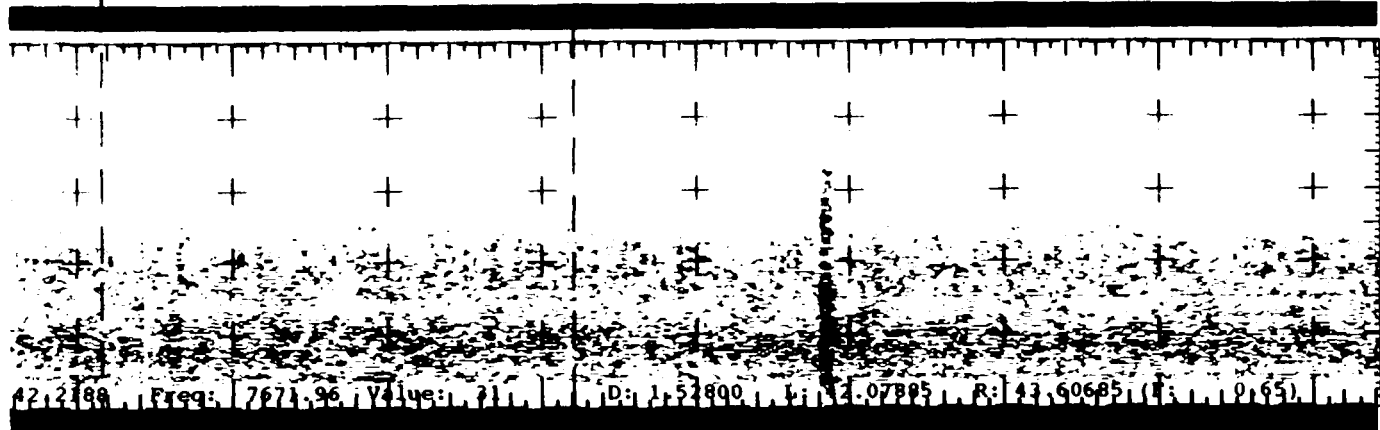


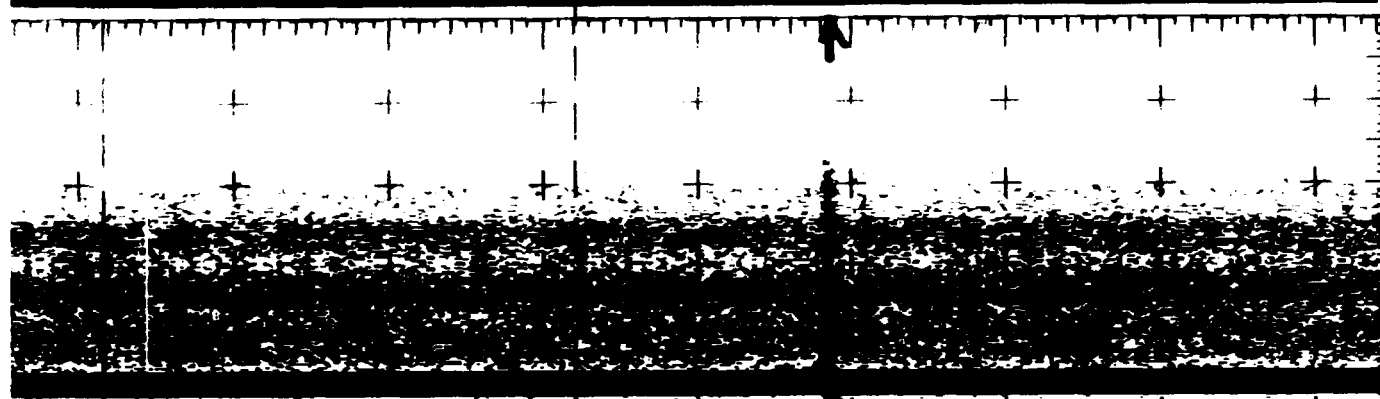
CHART F

CH 1 F1

42.2188 Freq: 7671.96 Value: 24 D: 1.52800 L: 42.07885 R: 43.60685 (F: 0.65)



CH -2



CH 3

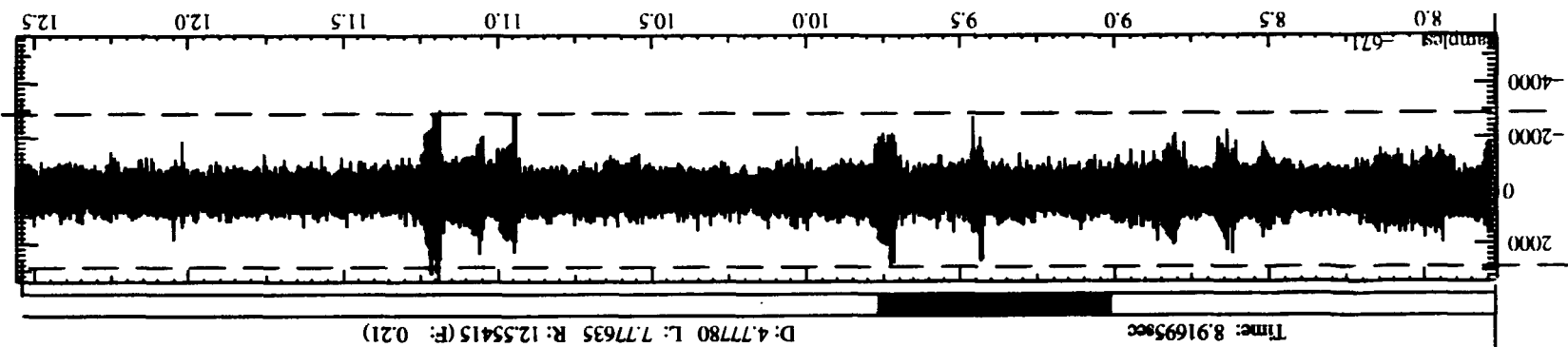


CH 4

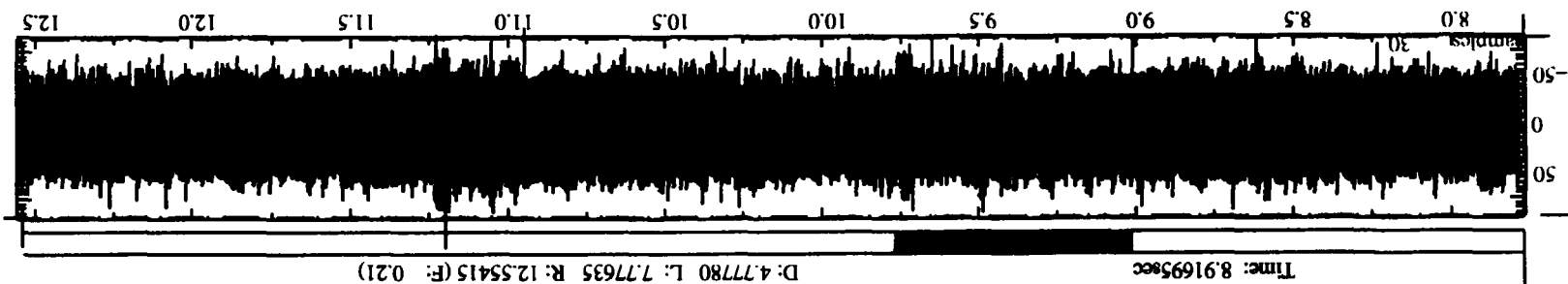
42 42.5 43 43.5 44 44.5 45 45.5 46

↑ 1.5 1.5

CH-4



CH-3



CH-2

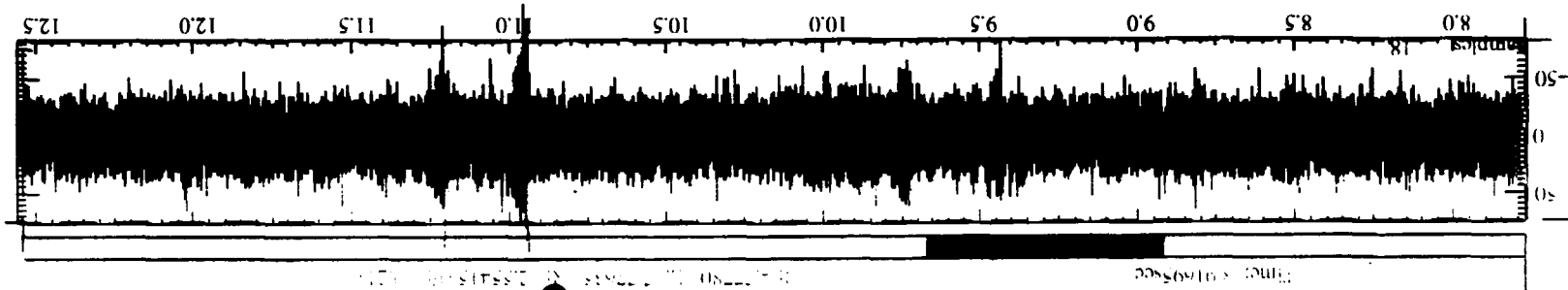


CHART 6

7.8980 Freq: 7720.21 Value: 25

0.0000

L: 11.91805

M: 12.11805 (F: 3.85)

CH-2

CH-3

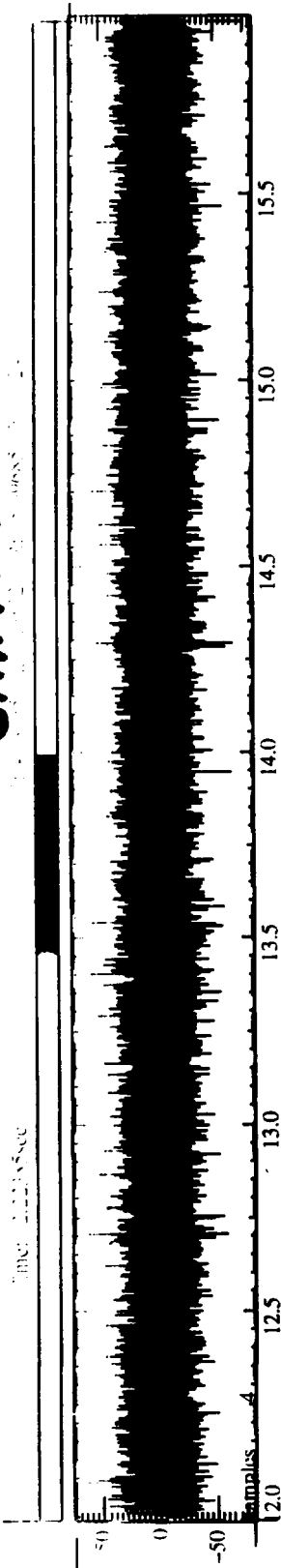
CH-4

19

seat belt  
clean →

CHRYST H

CH-2



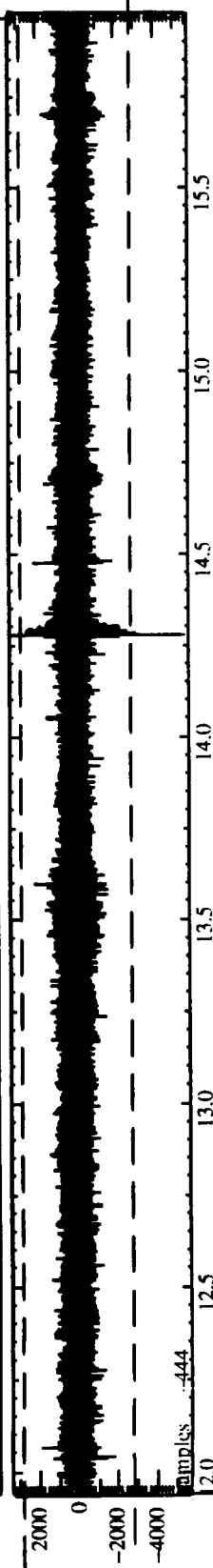
D: 4.08365 L: 11.91320 R: 15.99685 (F: 0.24)

Time: 12.22385sec



D: 4.08365 L: 11.91320 R: 15.99685 (F: 0.24)

Time: 12.22385sec



B

CH-4

CH-2

13.4527 Freq: 5274.26 Value: 21 D: 4.08365 L: 11.9132 R: 15.99685 (F: 0.24)

CH-2

CH-2

CH-4

21

13.5 13.5 14 14.5 15 15.5

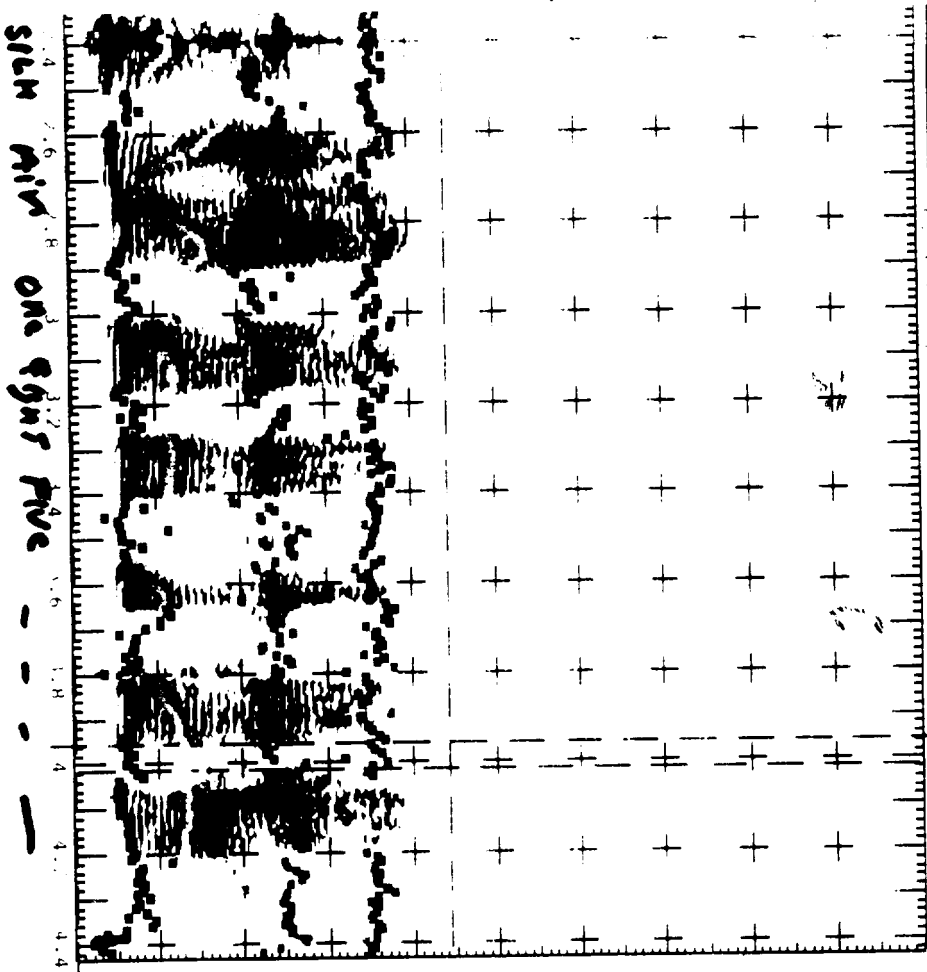
2.1648 Freq: 5769.23 Value 0.05300 L: 3.95685 R: 4.01485 (F: 17.24)

CNN 7 L

10K

Hz

0



CVR  
Radio

Red - 1st FORMANT  
Yellow 2nd FORMANT  
Green 3rd FORMANT  
Blue 4th FORMANT

CM 17

D: 2.31400 L: 2.11885 R: 4.43285 (F: 0.43)

2.2769 Freq: 3855.93 Value: 33

0000

0000

RADIO

one eight five

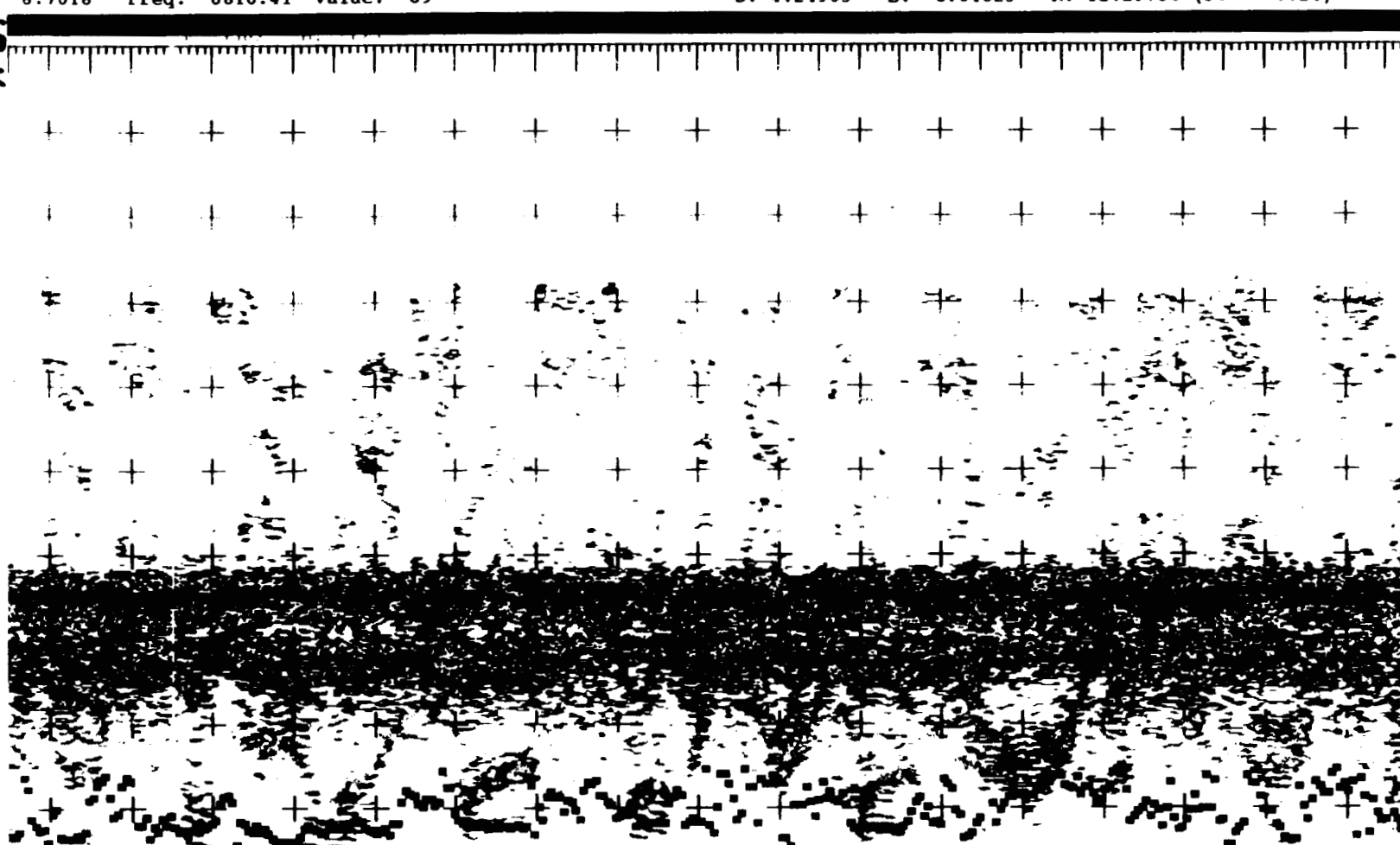
SIX

8.7018 Freq: 6816.41 Value: 89

CHARI N

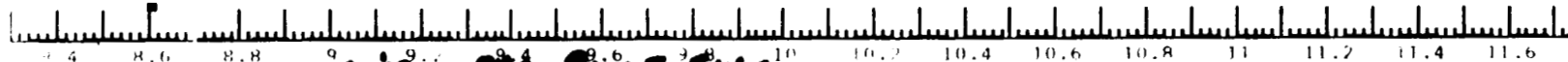
D: 4.24905 L: 8.04825 R: 12.29730 (F: 0.24)

121  
HE:



ATC  
RADIO

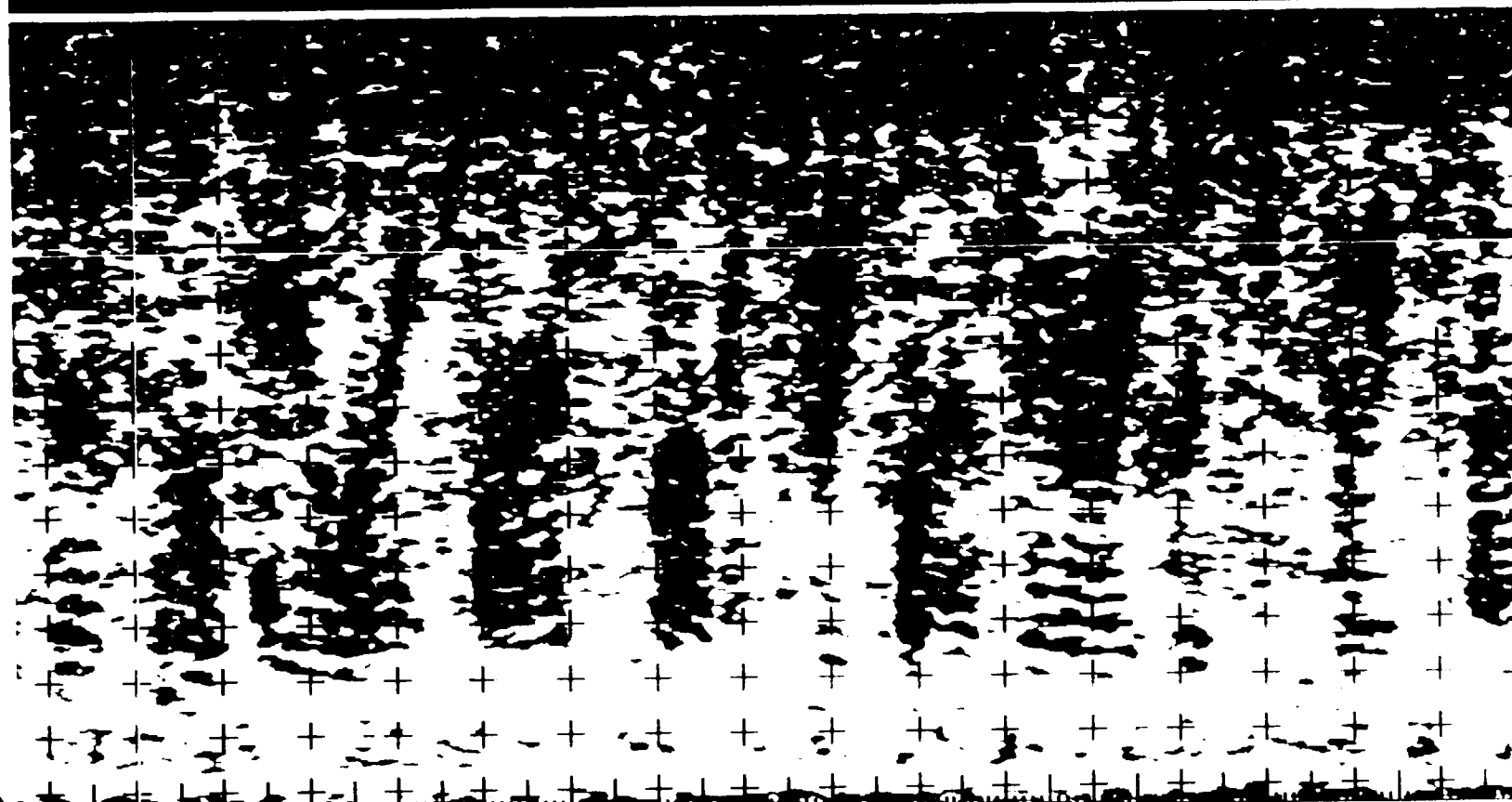
0



SILM . Air ONE EIGHT FIVE.

Red - 1st FORMANT  
Yellow - 2nd FORMANT  
Green 3rd FORMANT  
Blue 4th FORMANT.

3A  
Hz.



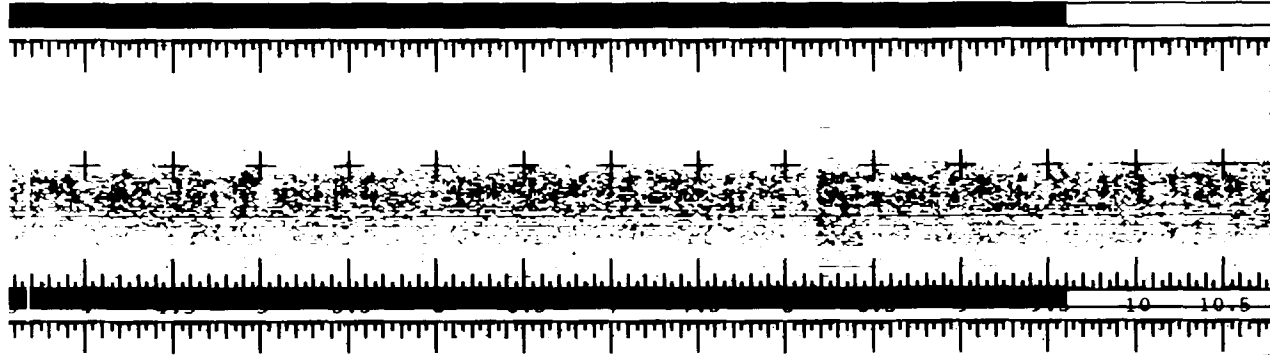
0

8.4 8.6 8.8 9.0 9.2 9.4 9.6 9.8 10.0 10.2 10.4 10.6 10.8 11.0 11.2 11.4 11.6

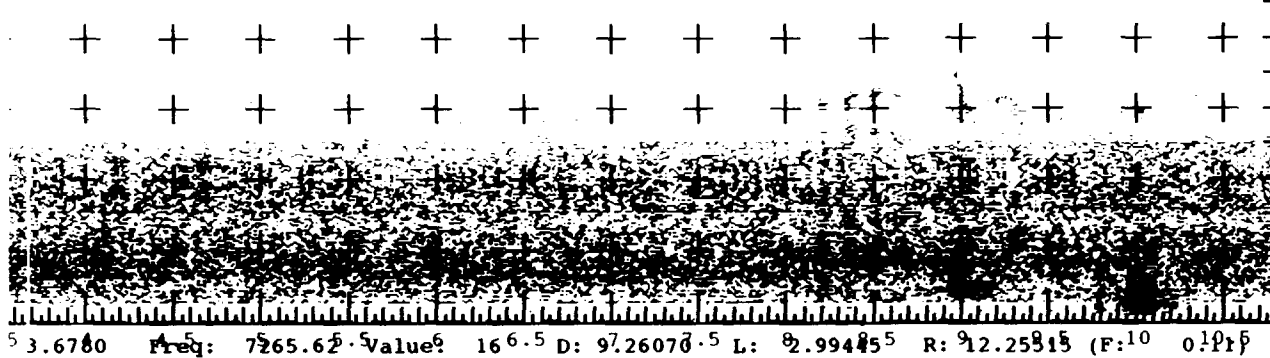
SILK AIR ONE EGYPT FILE

ATC  
RADIC

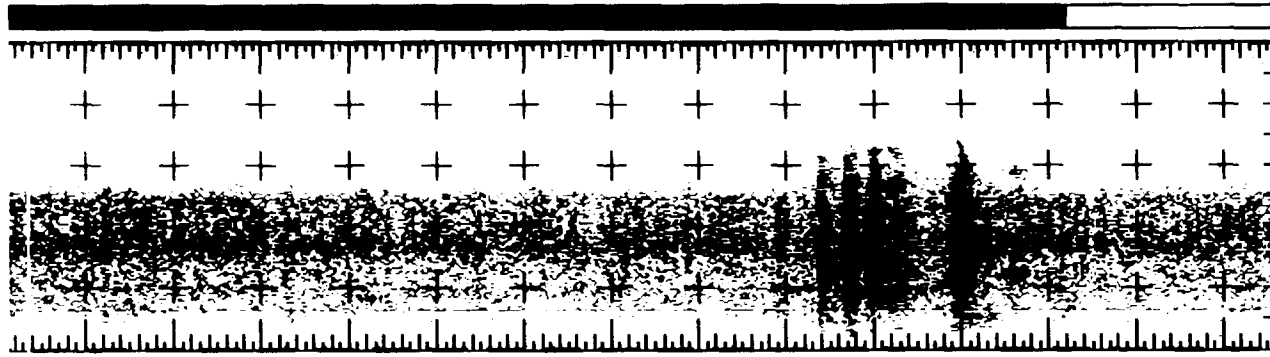
3.6780 Freq: 7265.62 Value: 10 D: 9.26070 L: 2.99445 R: 12.25515 (F: 0.11)



CH-1

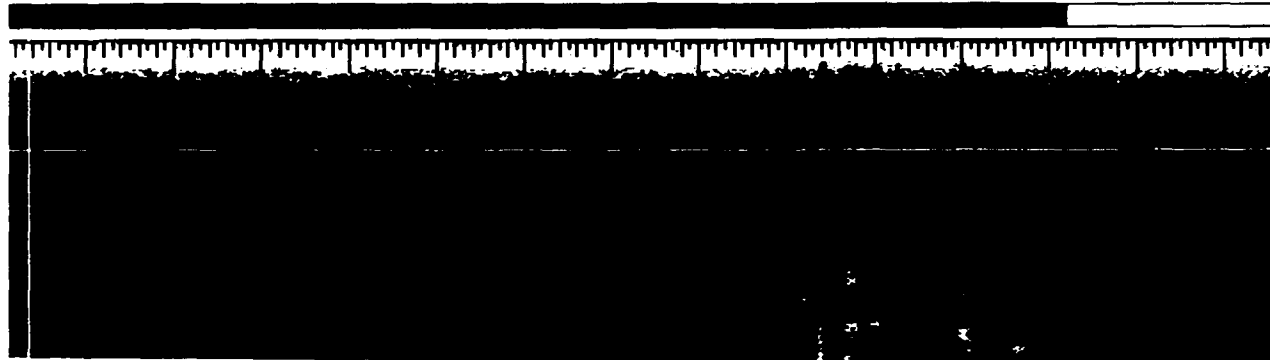


CH-2

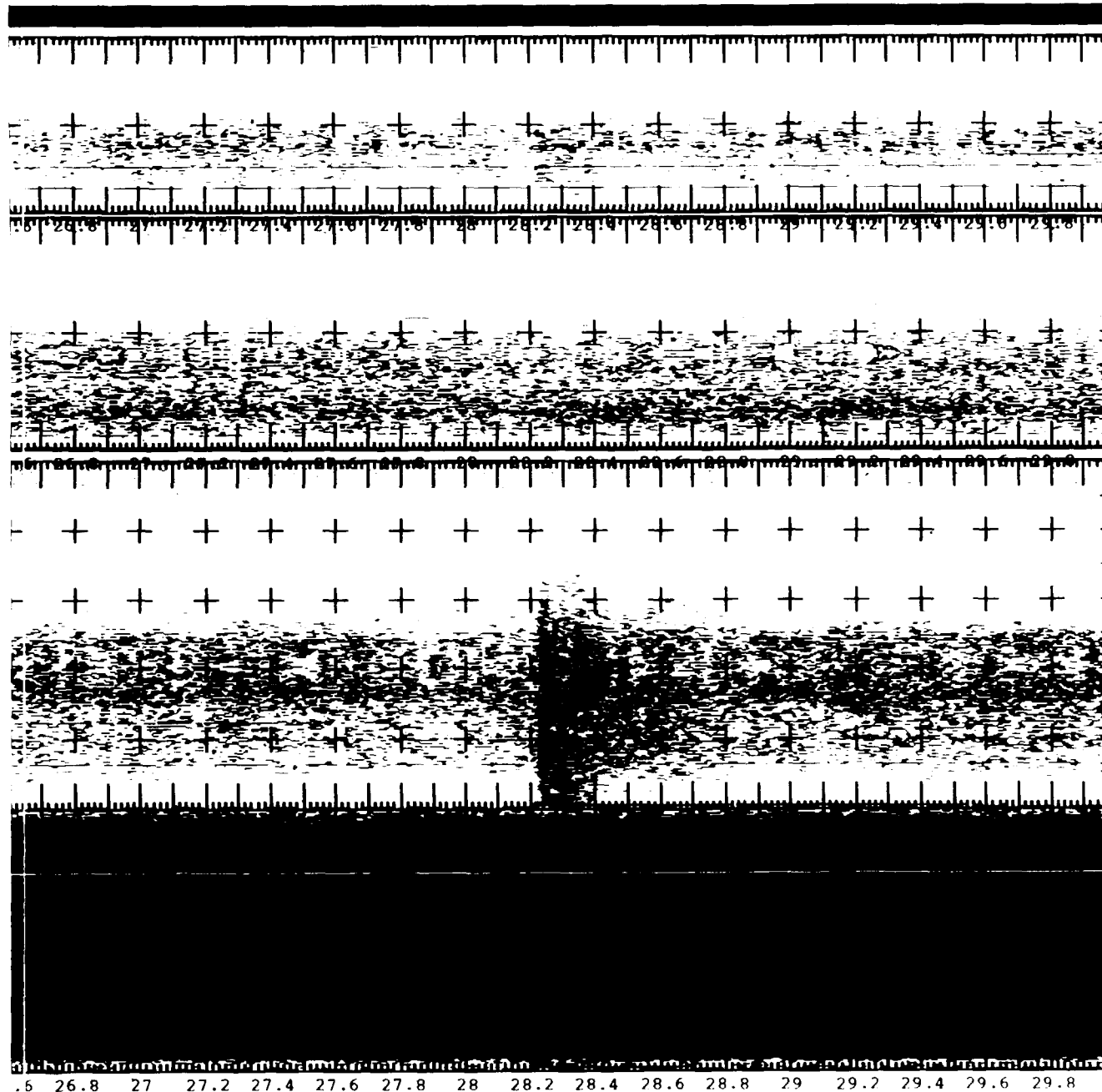


CH-3

3.6780 Freq: 7265.62 Value: 61 D: 9.26070 L: 2.99445 R: 12.25515 (F: 0.11)



CH-4



↑  
power  
↓

[illegible]

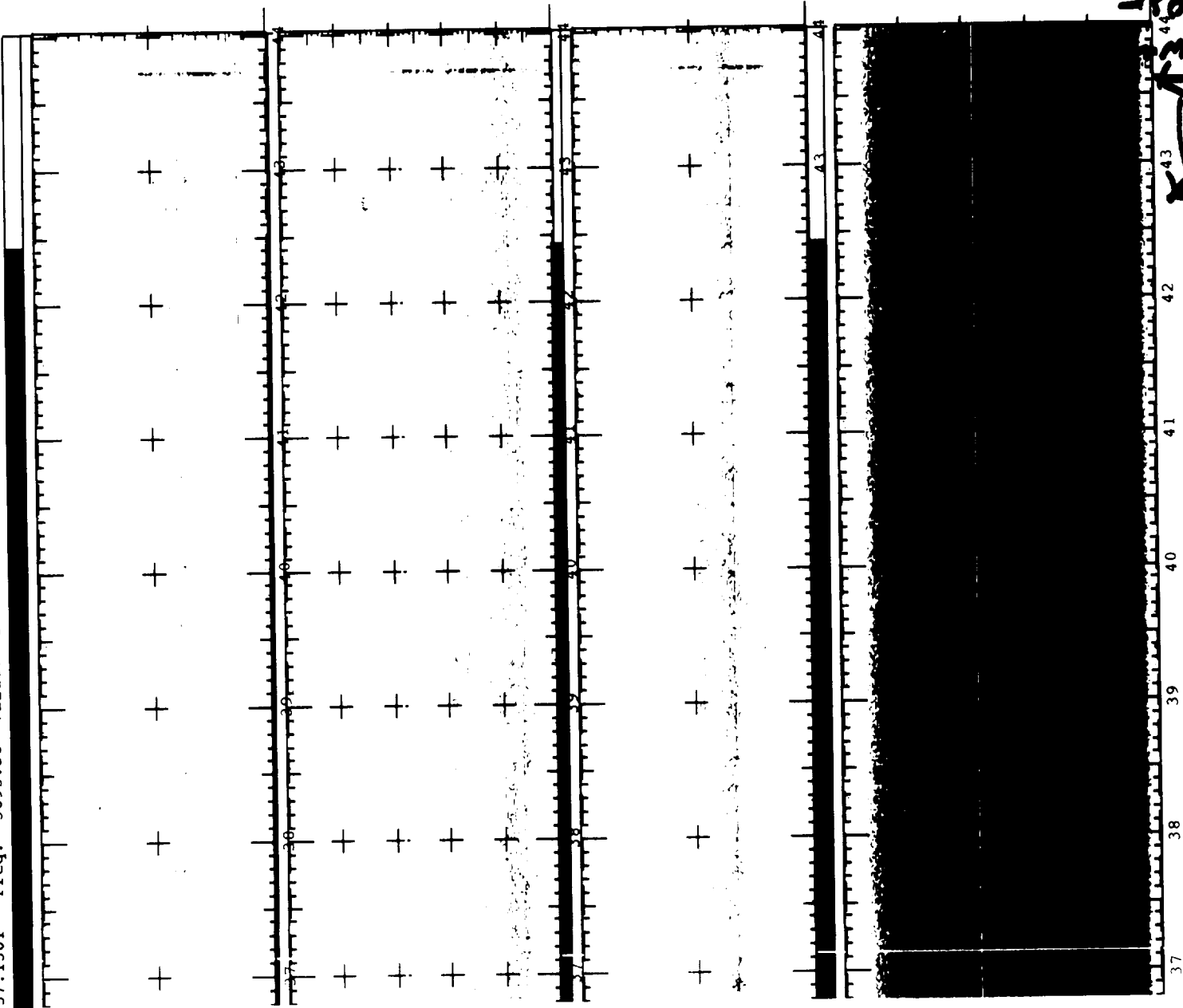
CH-1

CH-2

CH-7

CH-4

11



CH-1

70.3372 Freq: 8333.33 Value: 29

D: 7.82555 L: 69.20960 R: 77.03515 (F: 0.13)

CH-1

CH-2

CH-3

CH

CH-4

13

13

9.5810 Freq: 6750.00 Value: 23 D: 6.03210 L: 8.97545 R: 15.00755 (F: 0.17)

CH 2

9.5810 Freq: 6750.00 Value: 36 D: 6.03210 L: 8.97545 R: 15.00755 (F: 0.17)

CH 3

CH 4

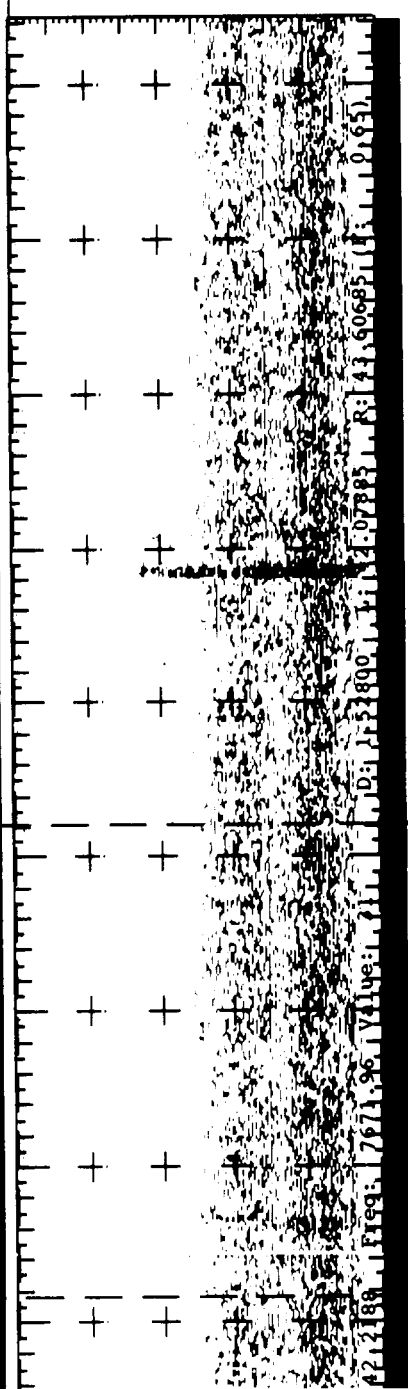
9.5810 Freq: 6750.00 Value: 23 D: 6.03210 L: 8.97545 R: 15.00755 (F: 0.17)

15

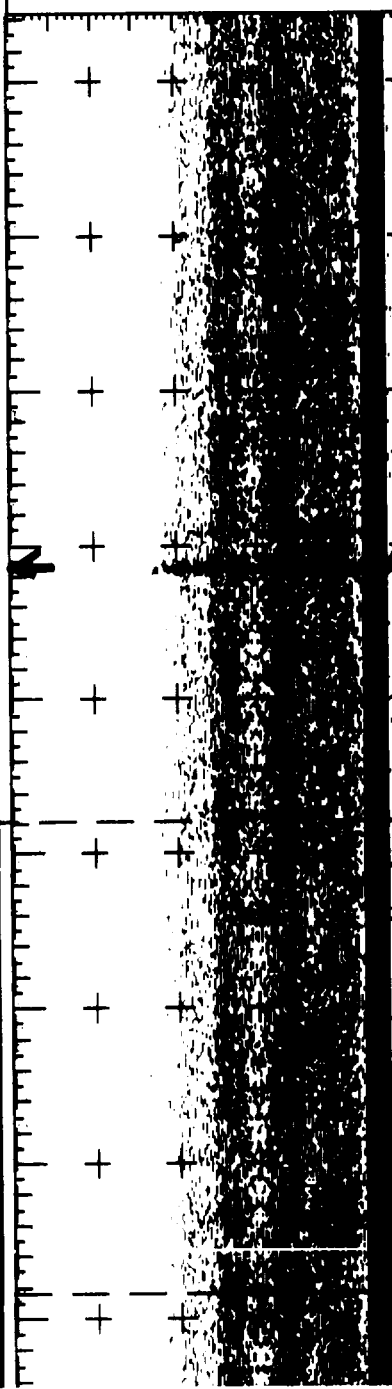
CH 4  
L: 8.97545  
R: 15.00755

CH 1 1

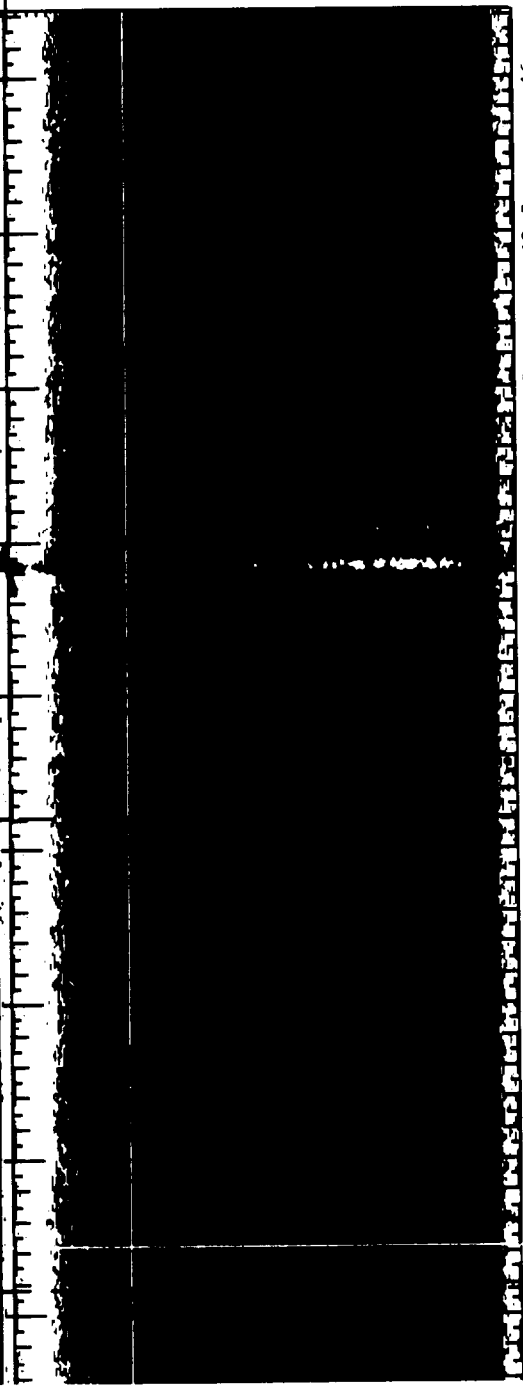
42.2188 Freq: 7671.96 Value: 24 D: 1.52800 L: 42.07885 R: 43.60685 (F: 0.65)



CH 2



CH 3



CH 4



1.52800

Freq:	Value:	L:	K:
7.8980	7720.21	11.91805	12.11805 (f: 3.83)

•  
•  
•  
•  
•  
•

**00000000**

50816.11 : 7

2) CNR/T-7T :M

CH-2

3-25

CH-4

9

5205 Bair  
C/UMH



CH-2

13.4527 Freq: 5274.26 Value: 21

D: 4.08365 L: 11.9132 R: 15.99685 (F: 0.24)

CH-2

CH-?

CH-4

12

12.5 13 13.5 14 14.5 15 15.5

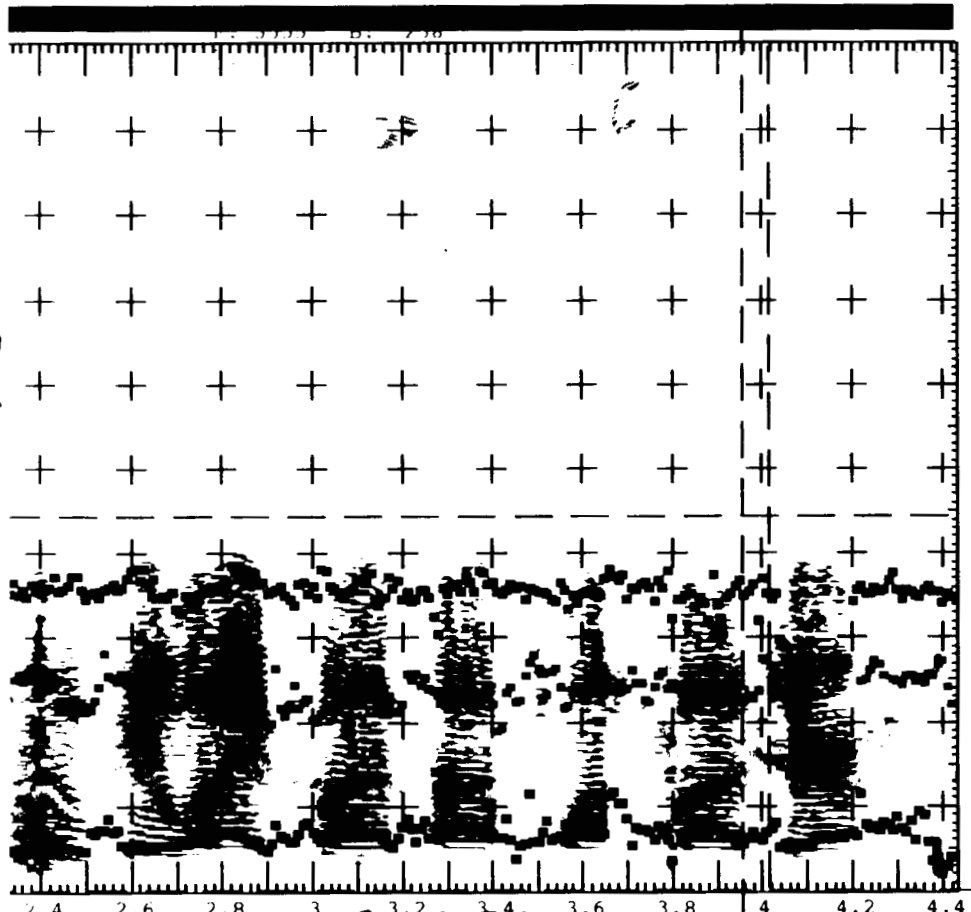
CHART 1

2.1648 Freq: 5769.23 Value 0.03200 L: 3.95685 R: 4.01485 (F: 17.24)

10K

Hz

CUR  
RADIO



2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4  
SILN AIR ONE EIGHT FIVE

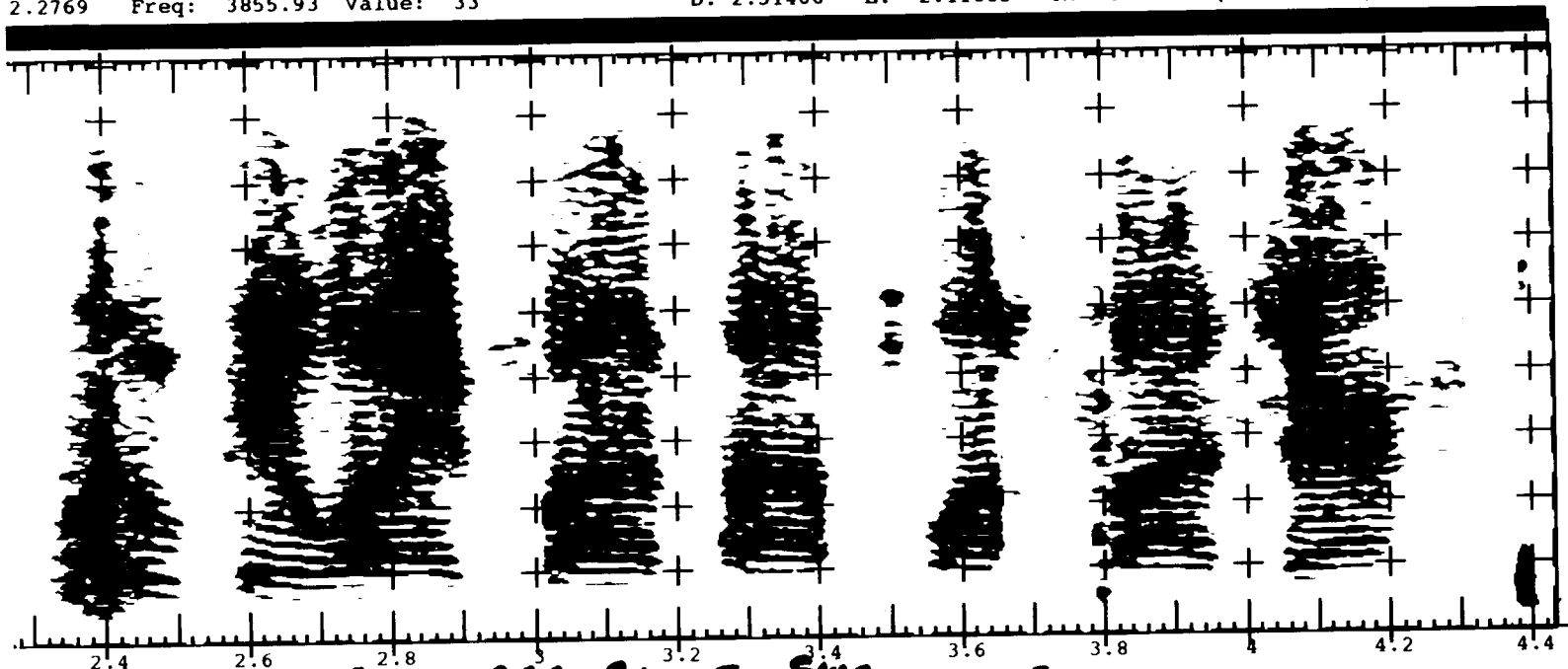
Red - 1ST FORMANT  
Yellow 2ND FORMANT  
Green 3RD FORMANT  
Blue 4TH FORMANT

2.2769 Freq: 3855.93 Value: 33

CAR 11 0  
D: 2.31400 L: 2.11885 R: 4.43285 (F: 0.43)

5000  
Hz

0 Hz



SILK

AIN

ONE EIGHT FIVE - - -

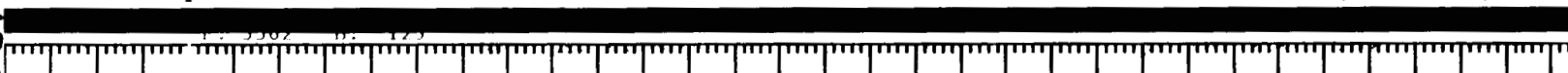
RADIO

8.7018 Freq: 6816.41 Value: 89

CMAP11A

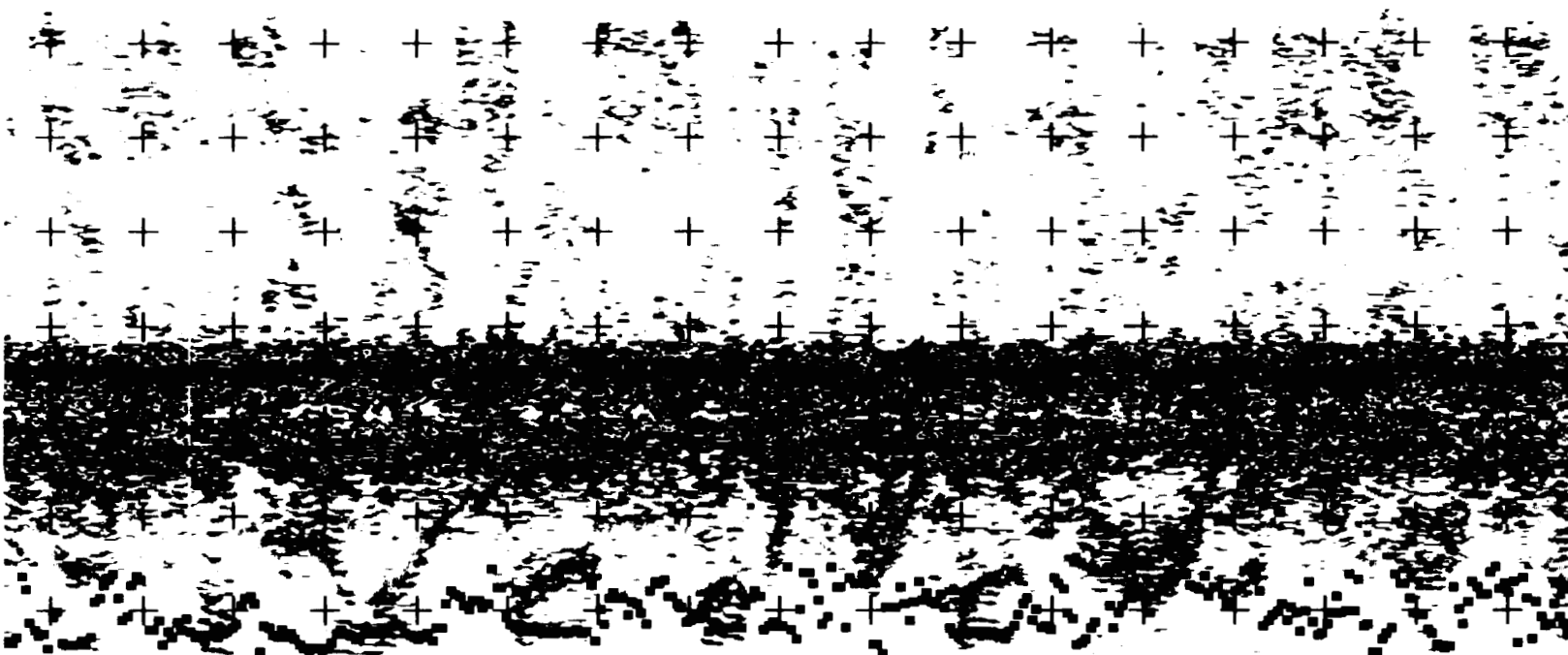
D: 4.24905 L: 8.04825 R: 12.29730 (F: 0.24)

12h  
42



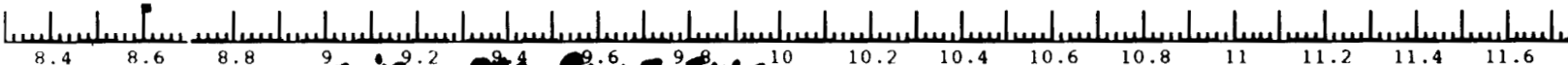
+ + + + + + + + + + + + + + + +

+ + + + + + + + + + + + + + + +



ATC  
RADIO

0



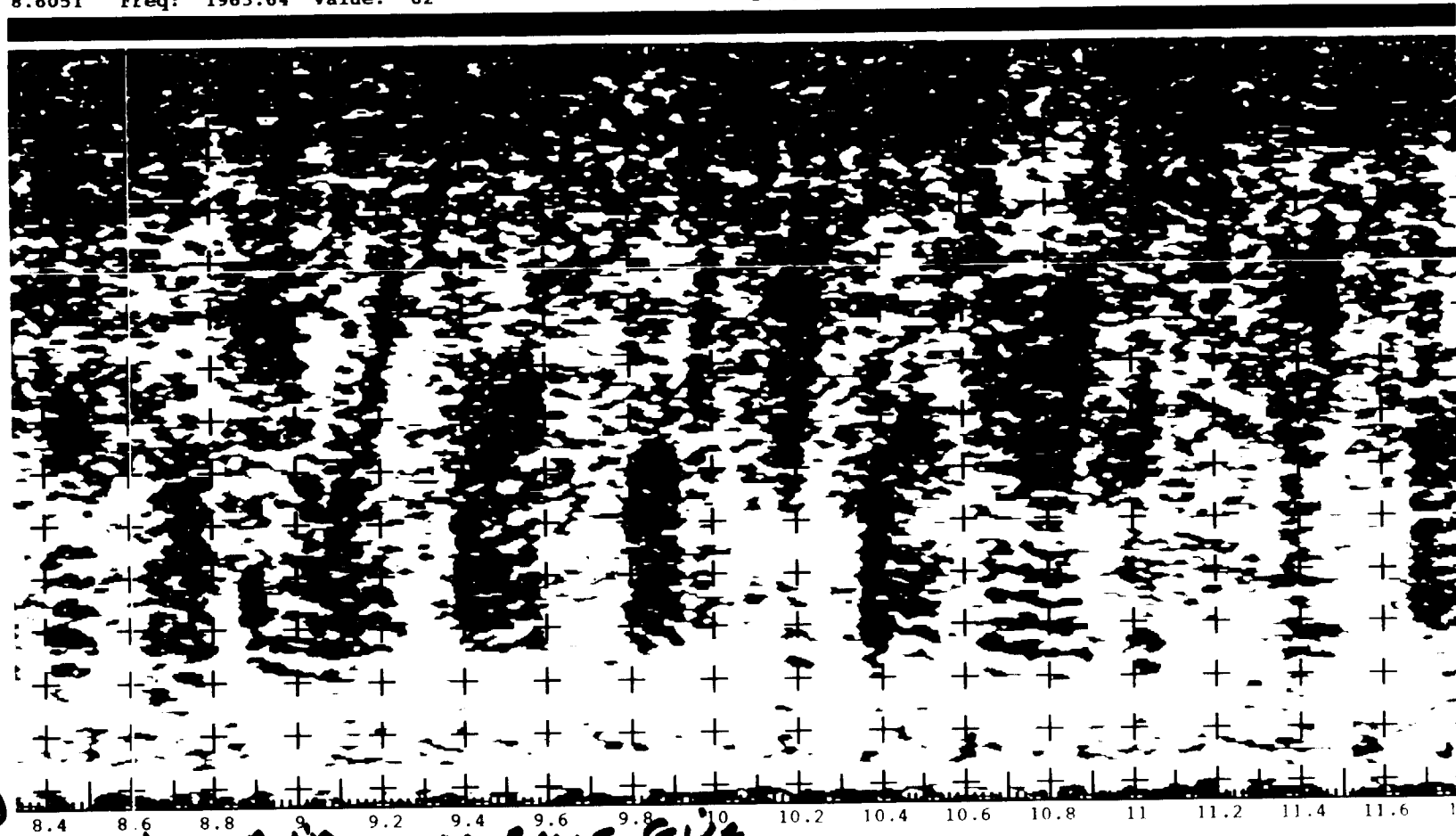
SILH Air ONE EIGHT FIVE.

Red - 1st FORMANT  
Yellow - 2nd FORMANT  
Green 3rd FORMANT  
Blue 4th FORMANT.

54

43.

0



SILK AIR ONE EIGHT FIVE

ATC  
RADIO